THE·BOOK·OF NATURE·STUDY

EDITED BY BRETLAND FARMER D·Sc:F·R·S

DISSECTED MODEL OF A TULIP

A.—Tulip Plant.

1. Bulb. 2. Flowering stem. 3. Flower. 4. Leaves. 5. Bulb scales. 6. Roots.

B.—Tulip Plant. C.—Tulip Flower Looked at from Above.
D.—Transverse Section of the Ovary of the Flower.

7. Base of old bulb-stem. 8. New bulbs. 9. Perianth leaves (*i.e.* petals and sepals). 10 and 11. Stamens (10, the anther; 11, the filament). 12. The Ovary. 13. Stigma. 14. The tissue of the carpels. 15. Ovule.


3
2
A
4
2
5
1
6

THE BOOK OF NATURE STUDY

INSECTIVOROUS PLANTS.

I. Butterwort. II. Bladderwort.
III. Pitcher Plant. IV. Sundew.

THE BOOK OF NATURE STUDY

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FULLY ILLUSTRATED

VOL. III

LONDON:
THE CAXTON PUBLISHING COMPANY
CLUN HOUSE, SURREY STREET, W.C.

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THE BOOK OF NATURE STUDY

PLANT LIFE

By Miss Charlotte L. Laurie,

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CHAPTER I

The Life and Growth of Seedlings

It is strange how little the majority of people realise that plants are living organisms. They are inclined to think of them as inanimate, and to wonder what Wordsworth meant by speaking of every flower enjoying the air it breathes, or the budding twigs feeling pleasure in spreading out their leaves. Now, although many scientists would hesitate to personify Nature as Wordsworth does, the fact of life which the poet is here emphasizing is indisputable.

Plants are capable of the same vital functions as animals. They breathe, they take in food, they respond to their surroundings in the most marvellous way, they grow, they produce other plants like themselves; in fact, they are capable of all the functions which are characteristic of life. Nothing is more interesting than to trace the adaptation of structure to environment, of which plants are capable. This is best studied in the various forms of leaves, in their arrangement on the stem, their hairiness, texture, etc. Some of the characteristic plants of the dry and sunny Australian climate have their leaves attached to the stem in such a way that they present the margin, not the blade of the leaf,

to the light. This is well seen in some of the plants now so commonly sold by florists. The Eucalyptus is an example of this, as is also the Acacia, though in the latter plant the "leaves" are really flattened leaf stalks. On the other hand, the majority of plants spread out their leaf-blades to the light, which is far less intense in our own climate. Again, Alpine plants like those found on the tops of the highest Scotch mountains, such as Ben Lawers, are often of much smaller growth, with small hairy leaves in rosettes, because in these high altitudes, owing to the special conditions of temperature and wind, it is important that the plant should give out as little water as possible, and the leaf surface is therefore considerably reduced, or very hairy. Plants of this kind are to be found even on hills not more than 800 feet high. The Stork's Bill, the Field Alchemil, the Alpine Pennycress may be mentioned. The leaves of water plants, as every one knows, are very different from those of land plants. Some have long, ribbon-like leaves, which can stand floods better than any other shape ; others have leaves adapted for floating, whilst a third set of water plants have leaves able to live and do their work entirely under water.

In plant life, too, there are quite as many interesting biological problems to be solved as in animal life. The phenomena of the distribution of plants offer a wide field to the speculative botanist. No satisfactory explanation of the flora of certain areas is as yet forthcoming. There is a district in Gloucestershire,—which shall be nameless, as there are some rare plants in it,—where certain species not present anywhere else in the county are to be found. How did they get there ? Supposing that the answer is, that certain seeds are carried long distances by the wind, still the puzzle remains : Why have these plants established themselves just in this small area and nowhere else in the county ? What conditions, or combination of circumstances, obtain there, and just there alone, that are absent in the immediate neighbourhood ? Or, to take another biological problem. There is abundant evidence of a struggle for existence going on between plants. This is being more and more realised, now that vegetation maps are being drawn in many parts. On certain Yorkshire moors, the bilberry is struggling with the cotton-grass. Where the moor is windswept and drier, the bilberry ousts the cotton-grass and

becomes the dominant plant. Trees even supplant each other. Warming states that in Denmark the oak has been replaced by the beech, whilst in West Jutland it is able to hold its own.

It will be clear from what has been said that the study of plant life is abundantly fascinating. Every one with even a small garden can watch the spread of a given plant, or the adaptation of structure, or the growth of seedlings. Even without a garden a great deal can be done with window boxes, with seeds in saucers, or in glass jam jars.

The habit of observing Nature brings with it its own delight, and, once begun, is not likely to be given up ; but the importance of a real, first-hand knowledge of Nature cannot be exaggerated in the case of those engaged in what is popularly called "Nature Study." The main object of Nature Study should be to develop the mental faculties of observation and reasoning. This cannot be done satisfactorily except by those teachers who are always finding out things for themselves, and constantly experimenting in one way or another, either repeating the experiments of others, or, still better, devising new ones, however small, for themselves. For this reason, constant reference will be made in this section to new work both in America and in Europe, and a bibliography will be given, in which the more recent botanical literature will be mentioned. Laboratory experiments are valuable, and in towns may be the only ones possible, but those who live in the country should be content with nothing less than observing Nature accurately and, like Gilbert White of Selborne, sympathetically and reverently.

In planning a course of lessons in Nature Study, it is important to be systematic. There should be one main thought underlying the course, just as there ought to be in a well-written biography. Nature Study courses not seldom resemble those biographies which are hastily compounded of newspaper articles, or letters from friends, strung together without any leading idea, as far as one can see, to form a bond of union. A course on Plant Life might have for its basis the adaptation of structure to function, or the manifestations of vitality common to both plants and animals. In this section, these are the root-ideas underlying the various experiments given and the facts of structure

that are recorded. It does not very much matter what the leading idea in the teacher's mind is—that must depend on the individual teacher—but it is important that the lessons should succeed each other in the order which best develops the conception that it is desired to impart of Nature and her ways.

Structure of Seeds.—The study of Plant Life may be begun with that of seedlings, and in order to understand the germination of a seed, it is necessary first to know its structure. If the seeds of various typical plants are examined, it will be found that the essential part of all seeds is the embryo of the young plant. Now it is obvious that the young plant must have something within the seed to feed upon until it is able to obtain food-material for itself from its surroundings, the air and the soil. This food-material is sometimes contained within the embryo, sometimes outside it. It is therefore necessary to examine several seeds, and the following will be found representative types :—1. Bean, pea, mustard and cress, cucumber, all of which have food-material contained in the embryo ; 2. Buckwheat, maize, wheat, barley, which have food-material outside the embryo.

To begin with the structure of the bean or pea. The mode in which the seeds are attached in the pod is shown in the folded diagram, inside the cover of Vol. IV. It will be noticed that the pod, or seed-vessel, splits into two pieces, an experience familiar to every one who has shelled peas. The seeds come off alternately in the two pieces, but are all attached to the same edge of the seed-vessel, each by a little stalk. It was by means of this stalk that the bean plant was able to feed the seeds when they were developing. The dry seeds of the broad bean are brown, convex on one side, and more or less straight on the other. The brown structure is the seed-coat ; on one side is a black scar showing the position of the stalk, attaching the seed to the pod. In seeds which have been soaked for twenty-four hours, the seed-coat, which was at first wrinkled, becomes stretched, owing to the water that has been absorbed. A triangular structure is seen through the testa, the apex of the triangle pointing towards the scar. This is the radicle, or first root. If a seed which has been soaked is dried on the surface and then squeezed, water will

be seen oozing out through a little hole, situated between the apex of the radicle and the black scar. It is through this hole that the root pushes its way. On removing the seed-coat the greater part of the seed is found to be occupied by two thick, fleshy lobes; these are the cotyledons, or first leaves, of the young plant. It is these that contain the food for the seedling. Between the cotyledons a structure continuous with the radicle is seen, namely, the plumule; this gives rise to the young shoot.

In the case of the bean, then, the seed consists of—

1. The seed-coat.

2. The embryo or young plant, the parts of the embryo being the two cotyledons, the radicle and the plumule. Note that the embryo fills the seed, and that the food for the young plant is contained in it.

With the bean may be compared the buckwheat. The seed sold by the seedsman is a fruit, for the outer brown coat is the wall of the ovary. It is a three-sided nut. On soaking these nuts for twenty-four hours, they swell owing to the absorption of water. The outer coat is then softer and can easily be peeled off, exposing the thin seed-coat, or testa, immediately underneath it. The whole seed then appears to be filled with a mealy substance. This is the food-material, called endosperm, or albumen; the food is outside the embryo, not contained in it, as in the bean. On gently scraping away the endosperm, the embryo is visible. The cotyledons are thin leaves folded in the endosperm, the radicle lies at the apex of the seed and the plumule lies towards the opposite end. This seed then resembles that of the bean in having two cotyledons, a radicle and a plumule; that is to say the embryos are alike in the two cases. It differs from the bean in having the food-material outside the embryo. It is an albuminous seed, whilst the bean is exalbuminous.

Germination of Buckwheat.—The Buckwheat germinates quickly in a moist, warm atmosphere. If several nuts are sown in boxes of soil, one seedling can be taken up every day, in order to see the stages of development.

1. The nut swells, and the radicle, making its way through the thin testa, bursts the outer coat of the nut at the apex by

splitting it into three pieces. It grows downwards, forming the primary root and giving off lateral branches.

2. The first thing to be observed above the soil is a structure in the form of an arch. This is the portion of the skin below the cotyledons, called the hypocotyledonary stem, or hypocotyl. During the first stages of germination the cotyledons are busy absorbing food from the mealy endosperm in which they are enfolded, and handing it on to the growing seedling.

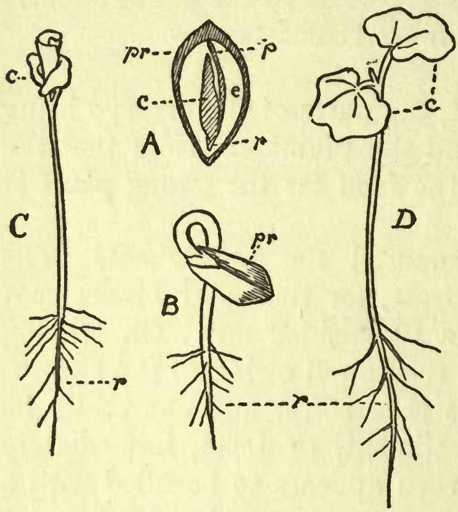


FIG. 1.—Seedlings of buckwheat. A, Section of nut of buckwheat; *pr*, outer coat; *c*, cotyledon; *r*, radicle; *p*, plumule; *e*, endosperm. B, Seedling of buckwheat with outer coat; *pr*, with coat still on. C, Seedling, with outer coat off and cotyledons folded. D, Seedling with cotyledons, *c*, spread out.

3. The hypocotyledonary stem next straightens itself, sometimes making a revolution, as shown in Fig. 1, at the bent portion. The two cotyledons are still folded in the nut.

4. Then the nut falls off, and this is the moment to observe the folding of the cotyledons before they expand. As soon as they spread themselves out they become green. The plumule situated between them is at first very minute, but it soon grows up, giving rise to the stem and foliage leaves.

STAGES TO BE OBSERVED IN GERMINATING SEEDS.—In watching the germination of seeds as just described in the buckwheat, the behaviour of the cotyledons, the elongation of the radicle, and then the development of the plumule should be noted. Observation of several typical seeds will show—

1. That germination is a much slower process in some than in others.

2. That the cotyledons behave very differently in different cases. Sometimes they remain underground, the young plant living for a time on the food contained in them. In other cases they soon appear above the ground, and begin to make food for

the plant from the materials derived from the air and the water taken in by the root. In certain types the cotyledons hardly develop at all, the seedling deriving its food from the food-material outside the embryo, as described in the buckwheat.

3. The mode of development of the plumule to some extent depends on the nature of the cotyledons. If these come above the ground very soon, they carry the plumule with them; but when the cotyledons remain in the ground, the plumule has to force its way through the soil, and it is very interesting to observe how it does this. It should be noticed, too, that the growth of the plumule does not take place until the radicle has reached a considerable length, for the young plant must have a grip of the soil before it can support the weight of a stem above the ground.

GROWTH OF SEEDLINGS.—In order to watch the growth of seeds, plant four or five sets of different seeds in boxes at intervals of about three days, so as to have seeds in different stages of development at the same time. Radish, mustard and cress, buckwheat, pea, bean, wheat, barley, maize are some of the best types. The patch where each set of seeds is sown should be labelled with the name of the seed and the date of sowing. As far as possible they should be kept in the same temperature. If the seeds are sown early in March, the boxes should not be left out at night on account of probable frosts, but it is as well to put them out during the day, provided they are not exposed to too hot sun. A good mixture of soil is two parts turfy loam, one part leaf-mould, half a part peat, and half a part sand.

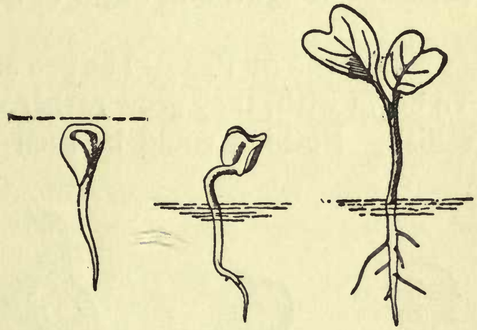


FIG. 2.—Seedling of radish, in three stages of development. The horizontal lines mark the level of the soil.

In about ten days' or a fortnight's time from sowing the seeds the cotyledons will be seen above the surface in the patch of mustard or radish. Each seedling has two cotyledons.

When they are first seen above ground they are pressed together looking like one leaf. Compare with these the seedlings of the seeds that were sown three days later. They are not yet above ground, therefore in order to see them the surface soil must be gently scraped away. The hypocotyl will be seen in the form of an arch, like the letter U turned upside down ; the cotyledons may be still within the seed, or possibly they may have just emerged. If they have come out of the seed, note that they are yellow, not green. It is by means of the arch that the hypocotyl is able to drag the seed-leaves out of the seed. As soon as the arch of the hypocotyl rises above the soil the two limbs of the arch begin to separate, this allows the inner surface of the arch to grow more quickly than the outer. The limb of the arch nearest the seed is helping to keep the seed fixed in the soil, whilst the other is tugging away vigorously at the seed-leaves, pulling them out of the seed. As soon as the cotyledons have been dragged from beneath the ground the hypocotyl straightens itself, the two seed-leaves which had been pressed together separate, turn green owing to the influence of light, and begin to make food for the young plant.

Seedling of Pea.—The pea and bean seeds behave differently. To begin with, they grow rather more slowly than the mustard or radish. Nothing could be seen above the soil till sixteen days after the seeds were sown. The broad bean was slower than the pea, and the kidney bean the slowest of the three ; it was nearly three weeks before there was any sign of growth above the soil in the case of the broad bean. The cotyledons of these three seeds remain in the ground, the epicotyl, or plumule—not the hypocotyl—making its way through the soil. Here, again, the arch form may be observed, by clearing away the upper layer of soil and examining peas or beans in different stages of development.

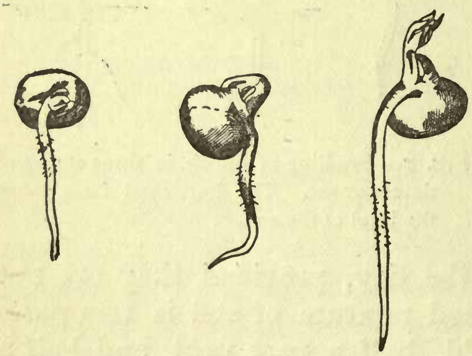


Fig. 3.—Seedling of pea.

In his work on the *Movements of Plants*, Darwin gives some interesting experiments which he devised in order to form some idea of the upward growth of the plumule after it had straightened itself. He found in the case of the common bean, that "the basal leg grew upwards with a force sufficient to lift a thin plate of zinc loaded with 12 ounces. Two more ounces were added, and the 14 ounces were lifted up to a very little height, and then the epicotyl yielded and bent to one side" (*Movements of Plants*, p. 88).

Hypogeal Cotyledons.—The cotyledons of some plants never leave the seed, partly because the testa does not readily split, and it is therefore difficult to extricate the seed-leaves. Those of the pea, the broad bean, and the kidney bean do not (although those of the dwarf French Bean and other species do); neither do those of the oak, the horse chestnut, and the walnut. In the month of May in an oak wood, numbers of acorns will be seen on the ground sprouting, with the cotyledons inside the nut; whilst in the beech, the holly, the gorse, and in the majority of trees and shrubs, the cotyledons will be found above ground.

As a rule, the cotyledons which do not come above ground are thick and fleshy, for they have absorbed all the food-material formed in the ovule after fertilisation. These are exalbuminous seeds. So too are the seeds of the radish, mustard, cucumber; but these have smaller and more delicate seed-leaves, which come above ground, turn green, and are able to take in food-material from the air and make food for the young plant.

The wheat, maize, barley form another group. They are albuminous seeds, *i.e.* they contain food-material apart from the embryo, in that part of the seed known as the endosperm.

Albuminous Seeds compared with Exalbuminous.—To realise the difference in the structure of a grain of wheat and the seed of a pea, soak a few peas and grains of wheat for twenty-four hours and then examine them. The seed-coat of the pea is tightly stretched, owing to the water absorbed, the outlines of the triangular radicle can be seen, the apex pointing towards the scar. On removing the seed-coat, the whole of the seed is seen to be occupied by the two cotyledons with the plumule between them,

and the radicle just ready to push its way through the testa. In fact, the seed of the pea consists practically of the seed-coat and embryo.

In the grain of wheat, the embryo is very minute and occupies but a small portion of the whole grain. Its position is indicated by the pale patch on the convex surface of the grain. The greater part of the grain consists of a white substance, the endosperm or albumen, which was formed in the ovule as a result of

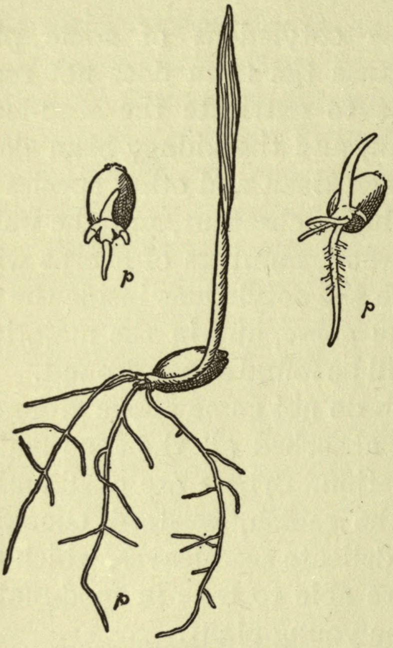


FIG. 4.—Seedling of wheat. *p*, primary root.

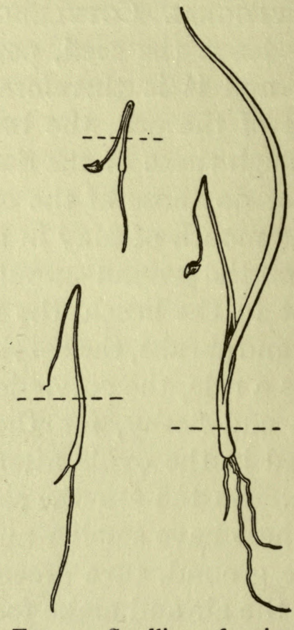


FIG. 5.—Seedling of onion. The dotted line marks the level of the soil.

fertilisation. The difference between albuminous and exalbuminous seeds is simply this ; in the former the food-material is not absorbed by the embryo, in the latter it is. The embryo is in contact with the endosperm by a shieldlike structure, the scutellum, which probably represents the cotyledon. The scutellum sucks food from the endosperm and hands it on to the young plant. The outer coat of the grain is the wall of the ovary, the seed-coat adheres to it and can only be detected with the aid of a microscope. The plumule of the wheat is curved, but does not form as complete

an arch as that of the pea or bean, for as the plumule is not situated between two cotyledons, there is not the same necessity for a vigorous pull. On the other hand, the onion does make an arch. Darwin notes (*Movements of Plants*, p. 87) that in germinating monocotyledonous seeds, the plumules are straight whilst breaking through the ground, and that those of the Gramineæ are likewise straight; their emergence from the soil is facilitated, he thinks, by the sharp crest in which they terminate. In the onion, the crown of the arch is developed into a white, conical protuberance which he considers helps the seedling to break through the ground.

The growth of the onion seedling is shown in Fig. 5. By gently scraping away the soil the grain is seen, and the arch form of the plumule. The level of the soil is indicated by the dotted line. As the seedling grows it frees itself from the grain, but sometimes this is carried up above the soil, as in the illustration. As the plumule grows, it gives off leaves which ensheath the stem. The root-system does not show a tap root, for in monocotyledons the primary root does not grow to any great length; the other roots soon equal it. A root-system of this kind is described as fibrous. The primary root can usually be detected by the sheath at its base.

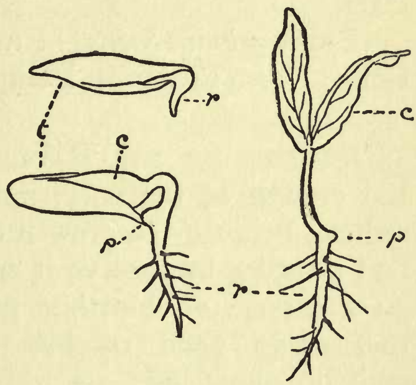


FIG. 6.—Seedlings of cucumber; *r*, radicle; *p*, peg of radicle; *c*, cotyledons; *t*, seed-coat.

The pumpkin and cucumber have a peculiar way of pulling the cotyledons out of the seed-coat. The general structure of the seed is similar to that of the bean; the radicle pushes its way out first and grows down into the soil. On its lower side it develops a peg, which holds down the seed-coat until the cotyledons have burst through the testa. Cucumber seeds must be grown under glass, and are very slow in developing, although, of course, much depends on the temperature.

The seeds already mentioned may be classified in the following groups :—

I. Seeds with Two Cotyledons.—*Epigeal Cotyledons.*—Radish, Mustard and Cress, Dwarf French Bean, Pumpkin and Gourd, Buckwheat, Horse Chestnut, Beech, Holly, Gorse.

Hypogeal Cotyledons.—Pea, Broad Bean, Kidney Bean, Oak.

II. Seeds with One Cotyledon.—Wheat, Barley, Maize, and those of all Grasses.

Or they may be grouped, according to the presence of food in the embryo or outside the embryo.

Albuminous Seeds.—Buckwheat, Maize, Barley, Wheat, Oats.

Exalbuminous Seeds.—Radish, Mustard and Cress, Beech, Holly, Gorse, Horse Chestnut, Pumpkin, Pea and Bean, Oak.

Growth of the Radicle.—Attention has been drawn to the growth of the cotyledons and plumule before that of the radicle, because the growth of a radicle takes place out of sight, and in order to observe it seeds must be grown in moist air, or on a sponge or blotting paper, in sawdust or in sand. All these give good results, provided the seeds have sufficient moisture, heat, and air. Mustard and cress grow very readily on a piece of sponge, suspended in a glass bottle with water at the bottom so as to keep the air moist. The mouth of the bottle may be covered with a thin strip of cork, leaving an opening on each side, in order that the air may have easy access to the seeds. The following is a diary kept of the growth of mustard seeds on a damp sponge :—

1907.

March 5. Seeds sprinkled on damp sponge.
,, 6–8. Seeds are swelling.
,, 9. The first root (the radicle) bursts its way through the seed-coat.
,, 10. Root-hairs appear behind the tip of the root.
,, 12. The seed-leaves come out and turn green.

1907.

March 15. The first bud (the plumule) can just be seen between the seed-leaves.

„ 30. The stem of the young shoot has given off two green leaves which are different in shape from the seed-leaves.

The bean seed is one of the best to grow in moist air, and the pea also answers well. The seed may be suspended in a glass bottle with a wide mouth by means of a blanket pin passing through the cork of the bottle and one of the cotyledons. There should be water at the bottom of the bottle. The bottle should not be tightly corked, for the seed requires air ; at the same time it must be sufficiently tightly corked to allow of the air inside the bottle being kept moist, otherwise growth is very slow. It is best, too, to keep the bottle in the dark, bringing it in to the light from time to time to examine the growth of the radicle, as most roots grow best in darkness. As far as possible the temperature in which the bottle is kept should be even and about the average heat of the room, say 60° F. If exposed to greater heat, the radicle will grow faster, but the temperature should as far as possible be kept the same. Two seeds may be fixed each in a glass bottle, one with the radicle directed downwards, and another with the radicle pointing upwards. As would be expected, the radicle grows downwards in the first case ; in the second, as soon as it has burst the seed-coat and grown a little, it curves and then grows downwards. Under normal conditions roots always grow downwards. Gardeners when sowing seed let it fall as it comes, for they know that in whatever position it happens to lie, the radicle will grow downwards.

In growing a pea or a bean in moist air, it is easy to show that growth is most active at the apex of the root. This is an experiment that can be set up during a lesson and watched from day to day in a classroom, if the bottles are kept in a cupboard in the room ; they may be examined at stated intervals and a drawing made of the radicle, say every twelve or twenty-four hours. The experiment is as follows :—Draw lines 2 millimetres apart in Indian ink across the radicle, an inch and a half in length.

The lines should be very carefully drawn to the very tip of the radicle. At the end of twenty-four hours the distances between the lines, which at first were equal to each other, are now very different, the greatest distance occurring near the tip of the root. This experiment shows that growth is most active just behind the tip of the root.

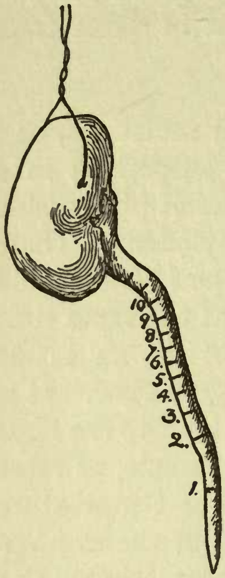


FIG. 7.—Radicle of bean, marked with transverse lines to show the region of greatest growth.

Another plan is to grow the bean in sawdust, then to mark the radicle with equidistant lines, and to examine the radicle at the end of every six, twelve, and twenty-four hours. Pfeffer in his *Physiology of Plants* (vol. ii. p. 8) gives a seedling of vetch (*Vicia Faba*), in which the end of the root had grown 4·6 millimetres in six hours and 20 millimetres in twenty-four hours.

Sometimes seeds do not give the expected results in moist air; when this is the case it is generally due to the air not having been kept moist, water has been lost by evaporation and by absorption into the seed, and has not been renewed. The advantage of moist air over sawdust is, that if the seeds are suspended in moist air to the cork of a bottle, they can be examined without disturbing them.

ACTION OF GRAVITY ON ROOTS.—That roots grow downwards owing to the action of gravity may be demonstrated to a class by means of a simple form of clinostat. A convenient form of this instrument has been introduced by taking a strong eight-day clock and fastening to the

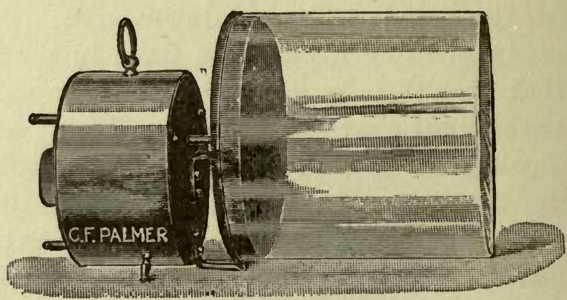


FIG. 8.—Clinostat.

axle of the minute hand a disc of metal or wood, faced with cork about 3 inches in diameter, so that it will revolve in a plane parallel to the face of the clock. A moist chamber may be then made of mica, which can be fitted to the edge of the cork. Seedlings of bean, etc., can then be pinned to the cork in various positions in the moist chamber thus constructed. The radicles of the seedlings will be revolving and will therefore not grow downwards. With this may be compared seedlings pinned in the same positions to a cork fixed in a similar moist chamber, but standing upright, not rotating. The radicles in this case grow downwards.

The Influence of Moisture.—Although roots grow downwards in obedience to the stimulus of gravity, they are even more strongly influenced by moisture. To try this, grow seeds in damp sawdust in a box the bottom of which consists of wire gauze. Then suspend the box in dry air, being careful to keep the sawdust moist. The radicles grow downwards through the sawdust, then they make their way through the wire gauze, and finding themselves in dry air, curve and grow upwards again, being attracted by the moisture in the sawdust.

It should be remembered that although roots require moisture, they do not thrive in stagnant water, for they need air as well as moisture. Nearly all plants flourish better in drained, than in undrained, land. Some of the advantages of drainage are, that the roots can penetrate more deeply, and not only air, but also water falling on the soil, can get into it. Moreover, this water often contains nutrient materials derived either from the air or from manure, which are thus supplied to the plant. Farming in England has been considerably improved of late years by good drainage.

The Influence of Light and Darkness.—Seeds grown in moist air, instead of being kept in a dark cupboard until the roots are fully grown, may be kept in the light. Then if one bottle is covered with brown paper, whilst the other remains exposed to the light, any difference in the growth of the radicle can be seen by comparing the two. A still better plan is to grow the

seeds in glass cylindrical vessels. Cocoanut fibre is wrapped in some porous paper and placed in the cylinder. The paper is kept moist. The seeds are sown on the paper next the glass. If exposed to the light, the radicles may be seen bending inwards and growing into the cocoanut fibre; if the glass cylinder is covered, then the roots grow straight down between the paper and the glass.

Growth of the Radicle in Soil.—When planting seeds in soil, it is usual to make a drill 1 or 2 inches deep, then to sow the seeds and to rake the earth gently over them. The weight of the soil on the seed helps to press it down and keep it fixed, whilst the radicle is making its way out and pushing down through the soil. When the seed is not pressed down in this way the root-hairs which are developed behind the tip of the radicle become attached to whatever surface they may be growing on, and thus hold down the upper part of the radicle, whilst the tip is forcing its way downwards through the soil, or sponge, or blotting paper, or whatever the substance on which the seed is growing. This is very well seen in barley grown on blotting paper kept moist in a glass jam jar. In about three weeks' time the roots will be several inches long, and if it is attempted to pull the seedling away, the blotting paper to which the root-hairs have attached themselves will also be torn away.

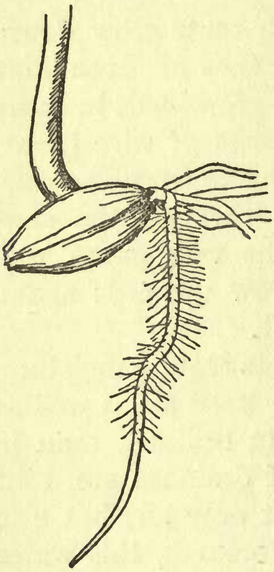


Fig. 8a.—Barley grown on blotting paper, showing root-hairs.

It is easy to see how a root penetrates the soil. The apex is always pointed and protected by a root-cap. The tip of the root grows rapidly in length and thickens. It is thus able to push away the earth on all sides. Darwin compares the force exerted by a growing root with that of a wedge of wood, which whilst slowly driven into a crevice, is made to expand owing to the absorption of water, and he remarks that a wedge thus acting

will split even a mass of rock. It is well known that roots help considerably in breaking up the subsoil; they also follow the track of earthworms, which, as it were, prepare a passage for the young plant.

Regions of the Root.—As a root grows, certain regions may be detected: (i.) The growing-point is just behind the root-cap.

(ii.) Next comes the elongating region, that is the part growing rapidly in length.

(iii.) Behind that is the region bearing root-hairs.

(iv.) Behind that again, the region which is growing in thickness and developing branches, *i.e.* lateral roots.

In order to see how the branches arise, the outer tissues nearest the branch should be scraped away, and it will then be seen that the branches arise internally; or sections may be made and examined under the microscope.

A transverse section should be made through the main root, just where one of the branches is coming off. In the accompanying figure the branch (L) is seen arising from the inner tissues from one of the bundles of the wood. It then pushes its way through the outer tissues, and grows out laterally from the main root. Although these lateral roots grow more or less horizontally, their tips bend downwards. This enables the root to reach those portions of the soil where nutriment and moisture are most abundant. These lateral roots are of special importance in trees. Both the birch and the beech are able to thrive in very shallow soil, on account of their immense system of lateral roots. Even where trees have a deep root-system, their lateral roots are of great use to them, for they usually extend horizontally to the circumference of the tree. Every one knows that it is possible to shelter under a tree during a slight shower, for until the foliage

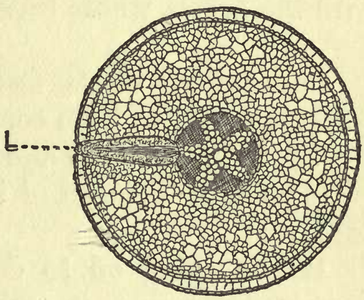


Fig. 9.—Transverse section through a dicotyledonous root. L, lateral root.

is wet through, the soil underneath remains dry. If the tips of the lateral roots did not reach the circumference, only soaking rains would be of any value to the tree. Teachers living in the country might encourage their pupils to observe the root-systems of trees as far as possible. They might notice, for instance, the exposed roots of the beech, supporting itself one hardly knows how on the deep banks of a country lane. Or the Scotch Fir (*Pinus sylvestris*) may be examined. This tree lives on dry, sandy soil, and is not usually easily uprooted, for the main root is deep and gives off widespreading lateral roots. When one of these trees is found uprooted, it will probably be seen that it has been growing in shallow soil, and has therefore only been able to form a short main root. Sometimes two trees, the one having a deep-rooted, the other a shallow-rooted, system, are found growing together. The oak and the beech are examples of this. The former strikes its roots into the soil sometimes to a depth of 5 feet, leaving plenty of room for the shallower system of the beech, and at the same time profiting by its association with the beech, whose leaves furnish it with humus.

Conditions of Germination.—So far, the first stages of germination have been considered, namely—

(*a*) The protrusion and growth of the radicle.

(*b*) The emergence of the cotyledons above the soil in many seeds.

Before going on to describe the development of the shoot from the plumule, it will be as well to consider more exactly the conditions necessary for germination, and, in fact, for the life of the plant. And here the teacher should proceed by means of experiments, in order to develop the reasoning power. The experiment should be as simple as possible, should be suggested by the student, and should be carried out with as simple apparatus as possible. In some laboratories unnecessarily expensive apparatus is sometimes provided. This is a disadvantage, for the simpler the experiment, the more likely is a student to repeat it at home.

To proceed from the known to the unknown is a very sound principle. It will be natural, therefore, to inquire whether

the conditions of growth in plants are similar to those under which animals and human beings thrive.

(i.) *Necessity of Air.*—It is a matter of common experience even to a child that no human being, no animal, can live without air. Is this true of plants? By experiment, it can be shown that air consists mainly of oxygen and nitrogen, the former being about one-fifth of its volume, the latter four-fifths. To exclude oxygen from seeds and to see the effect of doing so is the object of the following experiments.

1. Germinating seeds are grown on a sponge suspended in a bottle with some pyrogallic acid, dissolved in a strong solution of potash, at the bottom. The processes of germination are stopped and the seeds die, because the oxygen has been absorbed by the solution, and seeds cannot germinate without oxygen.

2. If germinating seeds are put in a glass bottle, tightly corked with an indiarubber bung, they will, in about twenty-four hours, or even less, have absorbed all the oxygen. A lighted taper plunged into the bottle at once goes out, owing to the absence of oxygen, and supposing the seedlings were left an indefinite time instead of twenty-four hours, they would die.

These experiments clearly show that seeds require air, for they must have oxygen. It is because germinating seeds need oxygen, if they are to live, that care has to be taken in the preparation of the soil of a seed-bed. It should be well separated and well drained, in order that air may make its way easily between the particles, so that the radicle as it grows into the root may get the oxygen necessary to its life.

The taking in of oxygen from the air is not the only chemical process going on in germination. It is a matter of everyday experience that the air of a room in which people are living requires renewing, otherwise it gets stuffy and gives headache to those who are obliged to remain in it. If some of the air in a stuffy room is collected in a glass jar in which some lime-water has been placed, the lime-water will turn milky, owing to the presence of carbon dioxide. To show a class the source of the carbon dioxide, it is merely necessary to breathe into a test-tube containing lime-water, then pressing the thumb tightly against the mouth of the test-tube to shake it well. The lime-

water turns milky. As lime-water always turns milky when carbon dioxide is mixed with it, it is clear that human beings breathe out carbon dioxide, and thus the air in a room in which people are sitting for some time gets laden with carbon dioxide. In order to ascertain whether seeds also breathe out this gas, the air in a glass bottle in which germinating seeds have been placed for twenty-four hours may be tested in the same way, by pouring a little clear lime-water into it and shaking it up. The lime-water becomes milky. The conclusion, therefore, is that germinating seeds give out carbon dioxide.

Experiments such as these are very simple, but they serve to develop the reasoning power, and help children to understand that respiration goes on in seeds as it does in human beings and in all animals; for the taking in of oxygen and the giving out of carbon dioxide always accompany respiration. What is true of seeds is also true of the fully grown plant; all the ordinary plants, as long as they are alive, are taking in oxygen and giving out carbon dioxide.

(ii.) *Water Essential.*—Seeds must have water; as long as they are in a dry condition they will not germinate. Some seeds can retain their vitality in a dry condition for years. Just lately Becquerel has experimented on the seeds of 500 species of plants belonging to 30 of the most important families of Monocotyledons and Dicotyledons. The age of the seeds was known from the records of the Museum of Natural History in Paris. He found that 18 species, 87 to 28 years old, of Leguminosæ; 3 species of Nelumbium, 56 to 18 years; one Lavatera, 64 years old; and a Stachys, 77 years of age, germinated.[1] Gardeners say that the best seeds to sow, best because most certain of producing good plants, should be a year old. There is nothing in the external appearance of a seed to denote whether it is dead or living, but as soon as it is soaked in water the living seed will begin to germinate; the dead seed will not. Seeds may be killed by boiling them, and then they will not germinate. Both living and dead seeds will take up water, but it is only in the living seed that the radicle will begin to protrude. It takes

[1] This, however, is not universally true; some seeds very soon lose their power of germination, and require to be sown the same year in which they are ripened.

some time for the seed to absorb as much water as it can take up. When a broad bean, or a pea, or, in fact, any seed is soaked, the gradual absorption of the water is evident from the stretching of the seed-coat. When dry, this is more or less wrinkled, but after three or four days the seed-coat becomes tense and splits, allowing the radicle to protrude. As seeds swell, they exert great force; it is stated that a large mass of swelling peas may lift 100 lb.

(iii.) TEMPERATURE.—*Seeds require Warmth.*—Seeds do not germinate without a certain degree of warmth. A convenient temperature is about that of an ordinary living room; anything between 21° C. and 35° C. will answer for the majority of seeds. Above a certain temperature, seeds will not germinate. Similarly, if exposed to too great cold, as, for instance, freezing-point, germination does not take place. It is advisable to keep germinating seeds in an equable temperature and rather moist air. One reason for planting hedges round fields is to protect the young crops from the strong, often very cold, March winds, which might injure the seedlings irreparably.

(iv.) *Germinating Seeds require Food.*—It is by the absorption of water and the food-material contained in it that young seedlings get their food. In the first few days of germination, seeds, like the bean, with fleshy cotyledons feed on the food contained in the cotyledons. In the case of seeds of rapid growth, like the radish and mustard, the radicle very soon develops root-hairs which absorb food-material from the soil. This food-material is taken in with the water. Even when the seeds are grown on damp blotting paper, or on a sponge, a certain amount of food-material will be absorbed with the water, for no water is absolutely pure. From ordinary tap water with mere traces of salts, plants manage to collect large quantities of mineral constituents, and in the case of water left exposed in rain-butts, or open cisterns, the impurities are considerable and furnish food-material for the innumerable algæ so commonly found in it. Seeds planted in soil get their food-material from the mineral substances present in the soil, from the leaf-mould and the manure, all these constituents being dissolved in water before the root-hairs can absorb them.

To show that substances must be in a state of solution, in order that they may be absorbed, the following experiment should be tried. Place a white narcissus in a tumbler containing red ink and water. The solution passes up through the stalk of the flower and colours its petals pink. Compare with this a narcissus placed in carmine and water. The dye does not find its way into the petals, for carmine does not dissolve in water.

It is the root-hairs on the roots that absorb water and the salts it contains. If seedlings are grown in sand, then taken up when the roots are some inches in length, that part of the root which has root-hairs will be covered with particles of sand. The best way of seeing the root-hairs is to shake the seedling in water, the sand comes off and the hairs are seen glistening in the water.

A seedling of wheat grown in soil and uprooted is shown. The root-hairs are covered with particles of soil. (See Fig. 14.) It is for this reason that in transplanting, it is most important not to injure the tips of the roots behind which the root-hairs are situated. If the soil is in a hard and dry condition, and the plant is roughly pulled up out of the soil, the roots are almost sure to be torn off in the operation. In such a case as this the ground should be thoroughly watered, the soil loosened with a fork or trowel, before the plant is taken out to be transplanted. Special care has to be taken with tap-roots, as it is very easy to break the tip by rough pulling. For this reason root crops, such as carrots, turnips, radishes, are seldom transplanted.

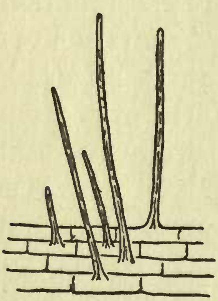


Fig. 10.—Root-hairs of barley projecting from surface of primary root.

In Fig. 10, root-hairs are seen projecting from the surface of the primary root of barley. Each consists of one long cell, with very delicate cell walls. The structure of the cells can only be seen with the aid of a microscope.

The work of the root-hair is to absorb food-material. The water with salts in solution enters through the cell wall, which is permeable. This is due to the fact that the contents of the cell are different in density from the water with salts in solution.

The following experiment illustrates this process. If the mouth of a thistle-funnel be covered with a tightly stretched piece of pig's bladder, and if the funnel, half-filled with a solution of sugar and water, be placed in a glass vessel containing water, some of the sugar and water will pass into the water and *vice versa*. The cell-walls of the root-hairs may be compared with the bladder; they allow of the passage of water, and substances dissolved in it, into the cell. Soil water necessarily contains those salts which are present in any given soil. Now, whilst water can enter and leave the cell freely, the salts contained in it are more or less imprisoned in the cell protoplasm, and have the effect of stretching the cell, producing the turgid condition on which growth depends.

It is clear that soils must have the elements necessary for the food of plants, if they are to thrive. The essential elements may be ascertained in one of two ways: either by analysing any given plant and thus ascertaining its chemical composition; or by growing plants in solutions containing certain salts, and seeing how they thrive. The first method is largely adopted in agriculture. The exact chemical composition of the crop to be planted in a particular field is ascertained, then the soil is analysed, and any deficiency of an essential element is made good by appropriate manure. It is hardly too much to say that right manuring makes or mars a crop, and may make all the difference to the profits of the farmer. A good deal may be ascertained by experimental plots. The individual plot should be about 20 square yards; the plant in question may be grown in a plot without manure, then in one with sulphate of potash, in a third with nitrate of soda, in a fourth with superphosphates, and so on. The plants obtained from each plot should be weighed under similar conditions. In this way the most appropriate manure may be ascertained. The second method of water cultures is of special value in laboratory work. Great care has to be taken in preparing the water culture solution; it is very difficult to get it absolutely pure, and also to prevent the seedlings "damping off." Any practical book on the physiology of plants gives methods of setting up water cultures, and experience soon shows which are the best seedlings to take.

Wallflowers and buckwheat, also pea, bean, and maize, give

good results; sunflowers do not. In Fig. 11 three seedlings are represented: A was grown in distilled, B in water culture solution minus calcium nitrate, and C in the pure water culture solution, which had been carefully sterilised. The drawing was made at the end of a fortnight, and certainly shows that C was thriving best. The glass vessels were wrapped in brown paper, in order to protect

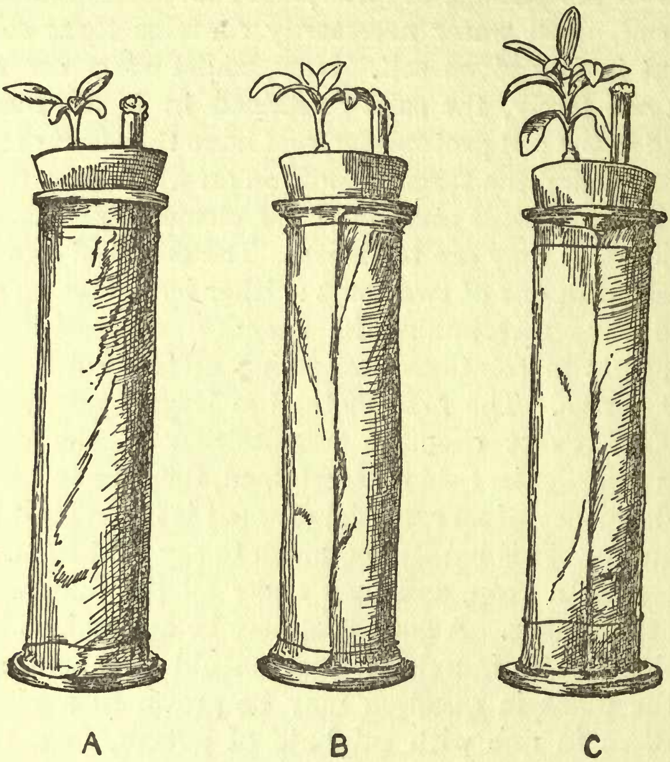


FIG. 11.—Seedlings of wallflower. A, in distilled water; B, in water culture solution minus calcium nitrate; C, in water culture solution.

the roots from the light. The effect of leaving out any salt, necessary for the food of the plant, can be thus demonstrated.

Experiments of this kind show that all plants require certain elements if they are to thrive well; but not all the mineral salts found in the soil are essential to every plant. It is a well-known fact that a chalky soil has a flora of its own, because certain plants must have lime. Others again hate lime, and are not found on either hard limestone or chalk. The preference of

certain plants for certain soils is the fact underlying the rotation of crops. In Norfolk, turnips are followed by barley, barley by clover, and that by wheat. Clover requires a great deal of potash, wheat very little; on the other hand, clover requires a great deal of lime, wheat hardly any. In some parts of Gloucestershire, the regular rotation is wheat, oats, seed grass and clover, roots; in other parts of the same county it is slightly different, wheat is followed by roots, these by barley or oats, and lastly comes clover and seed grass.

It has long been known, in fact since the time of Vergil, that leguminous crops were good for the ground, but it is only of late years that the reason of this has been ascertained. Experiments have shown conclusively not only that the soil is richer in nitrogen after a leguminous crop has been grown on it, but that the effect is felt even the second year when a cereal is planted. In his book *The Soil*, Mr. Hall gives the following account of some striking results: "A piece of land which had been cropped for five years by cereals, without any nitrogenous manure, was divided into two portions in 1872, one being sown with barley alone and the other with clover in the barley. In 1873, barley was again grown on the one portion, but clover in the other, three cuttings of clover being obtained. Finally, on 1874, barley was grown on both portions. The quantities of nitrogen removed in the crops of 1873 and 1874 are shown in the table:

"Nitrogen in crop—lbs. per acre.

1873.	Barley	37·3	1874.	Barley	39·1
,,	Clover	151·3	,,	Barley	69·4

"Thus, the barley which followed the clover obtained 30·3 lb. more nitrogen than the barley following barley, though the previous clover crop had removed 114 lb. more nitrogen than the first barley crop. An analysis of the soil was made in 1873, after the clover and barley had been removed; this showed down to the depth of 9 inches an excess of nitrogen in the clover land, despite the larger amount which had been removed."

It is clear from these experiments that leguminous plants enrich the soil, owing to their being able to use the free nitrogen of the air. During the last twenty years, this property of

leguminous plants has been the subject of much investigation in Germany, in the United States, and in England. The discovery by Hellriegel in 1886 that the power of using the free nitrogen depended upon the formation of nodules upon the roots has led to considerable research work. Pure cultures of the organism producing the tubercles on the roots have been obtained, and patient investigation has led to the working out of improved methods of making the cultures.

Root-Pressure.—The passage of substances in solution in the soil into the cells of the root-hair has already been described. Once absorbed by the root-hairs, the contents pass from cell to cell of the outer layers of the root until the fibro-vascular tissue is reached. These outer cells of the root may be said to pump the water with the salts dissolved in it into the wood, thence it circulates through the plant. This is what is meant by root-pressure. That roots do pump water into the wood may be demonstrated in the following way:—Take a small fuchsia or geranium plant in a pot, cut the stem across about 3 inches above the level of the soil, and below any of the lateral branches. Attach to the cut end of the stem by means of indiarubber tubing an empty glass tube and water will be forced into the tube to a height of 2 or 3 feet, if root-pressure is very considerable, as it is in the spring.

In order to measure exactly the force of root-pressure, apparatus such as that drawn in Fig. 12 is used. A T-shaped glass tube is attached by one end of the cross piece to the plant; by means of indiarubber tubing, the other end is tightly corked. To the centre piece of the tube, a U tube containing mercury is fitted. When the apparatus is set up, the mercury is at the same level in the two limbs of the tube. But as the sap rises from the stem into the T-shaped tube it flows on into the U tube, forcing the mercury into the right-hand limb of the tube. The difference in the column of mercury in the two limbs gives the column of mercury which is supported by the sap, and is a measure of the force of the root-pressure. Regular observation and accurate measurement shows that the root-pressure varies not only at different seasons, but at different times of the same day.

Root-pressure it is that makes plants bleed when pruned.

The art of pruning requires great care. It is easy when the shoots are leafless as in winter, and all that has to be done is to cut out the thin twigs in the centre. Summer pruning may take place any time from the end of May. The young vigorous shoots of the current year have to be restrained, as they are draining the sap from the roots. These shoots when they are about 6 inches or a foot long are just pinched at their tips; a fair number of leaves should be left and then the sap is just drawn past the buds, which practically remain dormant until the next year. The short shoots, with the leaves in a rosette round the terminal bud, do not, as a rule, require pruning, neither do those bearing blossom. Not only is the amateur gardener apt to cut the wrong shoots, but he is apt to cut in the wrong way. It is said that there are about 359 wrong ways to cut a shoot, but only one right way. The cut should be begun on the opposite side of the stem to that on which the bud which is to be left is situated, and the cut should pass through an angle of 45°.

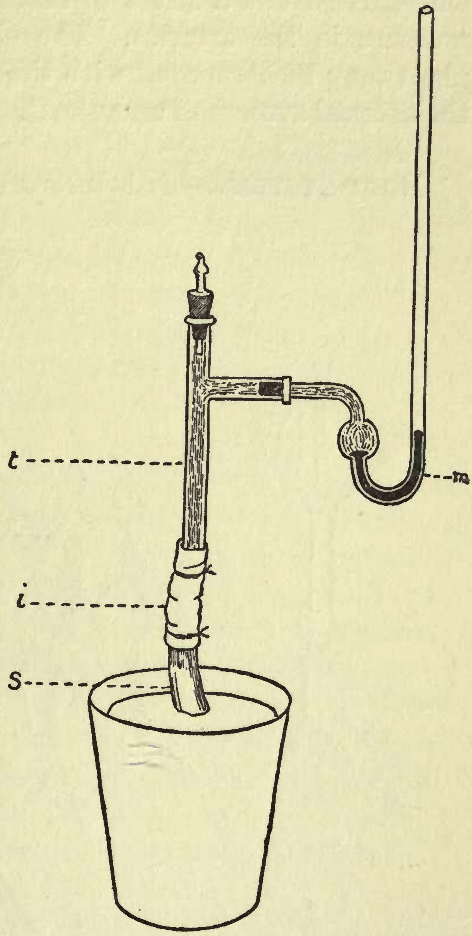


FIG. 12.—Apparatus for measuring root-pressure. *t*, a T-shaped glass tube; *i*, india-rubber tubing; *s*, stem; *m*, mercury.

Roots themselves are sometimes pruned in mild weather in the autumn or winter, either to prevent too rampant growth, or to induce fruitfulness. If roots are growing very rapidly and spreading through the soil very freely, they take up food very vigorously, fresh shoots are formed, and the flower

buds do not ripen. On the other hand, if the roots are not growing properly the tree is not getting enough food to produce fruit.

One of the first experimenters on root-pressure was Hales, who carried out a series of investigations on the force of blood-pressure in the arteries. The circulation of the sap through a plant may be compared with the circulation of the blood through the arterial system of an animal.

ROOT-SYSTEMS.—It is interesting to compare the root-systems of various plants. Some have a main root growing straight down into the soil, with lateral roots developed in vertical rows. This is the tap-root system. The number of these rows varies. The typical number in dicotyledons is four; the beetroot shows two sets of rows, and many plants have five or more. The older parts of the root keep the plant firmly fixed in the soil; the extremities of the roots, where the root-hairs are, absorb the food-material.

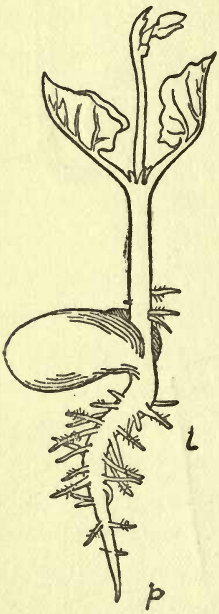


FIG. 13.—Root-system of bean. *p*, primary root; *l*, lateral roots.

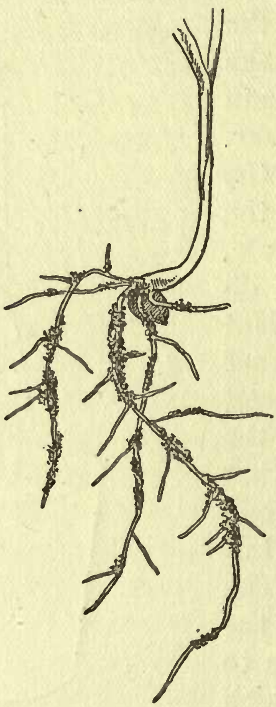


FIG. 14.—Root-system of wheat, with grains of sand attached to roots.

In some cases, particularly in plants growing by the sea, the tap-root is very long, so as to penetrate the deeper layers of the subsoil and thus get as much water as possible. In prolonged drought the depth to which the roots can penetrate may make all the difference to the possibility of the plant surviving the long spell of dry weather.

Some plants have a fibrous instead of a tap-root system. This is characteristic of grasses. Here there is no main root seen; but there are several roots, all of about the same length, and these give off smaller roots. A root-system of this nature is not strong enough for a plant that grows very tall, and even in the case of some grasses, such as maize, which grow very high, fibrous roots are not sufficient. The maize develops rings of roots from the stem above ground. These grow downwards, and when reaching the soil they help to keep the plant fixed firmly.

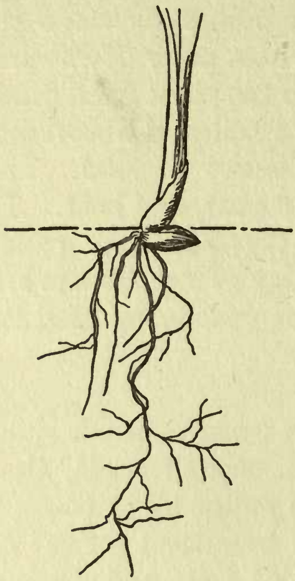
Besides fixing a plant firmly in the soil and absorbing food-material, roots are often great storehouses of food. They are then usually swollen, as in the turnip, carrot, and beet. The two former contain grape-sugar, whilst the beet has cane-sugar. Plants which have roots capable of acting as storehouses are often biennials, the food that is stored up one year being used the next for the production of flowers and fruit.

Depth at which Seeds should be Sown.—Seeds should not be sown too far beneath the surface. Small seeds, those, for instance, of plants that are going to be pulled up or transplanted, like lettuce, radish, spinach, are sown broadcast on the surface, for they require very little covering of soil, and after sowing it is sufficient to rake the soil lightly. Even these small seeds are often planted in drills, a more economical method. Drills, as every amateur gardener knows, are tiny furrows from ½ inch to 2 inches or so in depth, according to the size of the seeds to be sown. Sweet-peas may be planted 1 or 2 inches below the soil. Supposing seeds are sown too deep, the plant may not be able to reach the surface.

The accompanying illustrations of oats planted at different depths show that a grain planted too deep forms a few roots, then when the epicotyl has reached the right level for the plant, a second root-system is formed. If planted much too deep, the plant might have such difficulty in reaching the surface that it might die, or it might be at such a disadvantage, that it could not develop properly.

In this connection it may be mentioned that the roots of certain plants as they get older have the power of pulling the

plant down deeper into the soil. This may be observed in lords and ladies, or arum, in the crocus, and in many other plants. It is due to the fact that the oldest part of the root—that nearest the stem—at a certain age shortens or contracts, owing to changes that take place in the outer cells. These grow shorter in the longitudinal direction, and at the same time often increase in width. The apical portion



FIGS. 15 and 16.—Oats sown at different depths. The dotted line marks the surface of the soil.

of the root has reached a good depth in plants of a certain age, and as the tips of all the branches have become more or less firmly fixed in the soil, the effect of the shortening of the older portion of the root is to pull the whole plant downwards. A contractile root may be recognised by the transverse ridges and furrows which mark it. In the arum the contractile roots arise on the tuber in the late autumn. In the crocus, they are found at the base of the young corn in the spring, and they sometimes even pass through the old corn, situated underneath the young one. Those who have gardens and would like to try experiments on the depth to which bulbs, etc., may be

pulled down by contractile roots, should consult Professor Oliver's paper, "The Depth in the Soil at which Plants occur," in the April number of the *Royal Horticultural Society Journal*, 1898.

Aerial and Parasitic Roots.—There are not many plants with aerial roots in this country, but in the tropics they are very common. Ivy climbs by means of the roots borne by its stem. Like all roots, they are very sensitive to light, and like to get away from it. The overshadowing leaf no doubt protects them from too strong light, and it is in all probability the influence of light which makes the roots penetrate every chink and cranny they can, often to the great destruction of the wall. Many orchids have aerial roots. In the tropics, orchids often grow on other plants and climb from one to the other by their roots. This does not injure the plant, for the food of the orchid is chiefly derived from the dust which falls on the root, moisture being obtained from the heavy dew. The orchid is therefore hardly a true parasitic plant. In this country, there are many semi-parasitic plants, getting their food partly from the air through the activity of their green leaves, and also from the plant on which they are living. These all send processes from their roots into the plant on which they are living, and thus get part of their food from them. The red and yellow rattle and the eyebright are semi-parasitic plants.

The mistletoe is a true parasite, very fond of the black poplar and apple trees. The seeds are dispersed by birds, chiefly thrushes, which eat the mistletoe berries. The seeds become stuck on the bark of the trees, and remain there some months before they germinate. When germination begins, the radicle becomes attached to the bark and puts out a process called a "sinker," which grows into the tree.

The young seedling of the mistletoe is then fed by the food taken from the tree. If it is growing on the poplar, its growth is generally luxuriant, but if its "host" is a tree from which only a limited amount of nourishment is derived, then the growth is scanty.

Suggestions for Practical Work.—The contents of a greengrocer's shop will afford material for three or four lessons

on roots. Country walks will give opportunity for observation of plants and their adaptation to their habitat.

1. The difference in the shape of tap-roots may be illustrated by a comparison of the carrot, the turnip, and the radish. These should all be drawn.

2. The fact that roots are storehouses will be evident on examining the beetroot, the carrot, the turnip, and the spinach. The nature of the food-material stored can be tested by rough-and-ready methods. It is often possible to detect sugar by taste, as in beetroot and carrot ; starch by iodine.

3. The roots of leguminous plants should be examined for tubercles. Their presence is a sign that these plants are using the free nitrogen of the air. This can be done by digging up clover, which is so often planted for fodder.

4. The root-systems of different typical plants may be observed by growing germinating seeds of the plants between cocoanut fibre wrapped in porous paper and the side of a glass cylinder. Maize, pea, wheat, sunflower are suitable.

5. The difference in root-systems, according to the habitat of the plant, may be studied in walks planned for the observation of Nature. Plants growing in dry situations often have long tap-roots. The difference in the firm attachment of the plant in the soil when the root-system is deep, and when it is shallow, is soon seen in the comparative ease with which it is possible to pull up a shallow-rooted plant.

As far as possible, students should try and make their own observations, and not be content with seeing an experiment performed in class ; it is only in this way that it is possible to get to know with first-hand knowledge something of the vital activities of plants.

Foxglove.

Mullein.

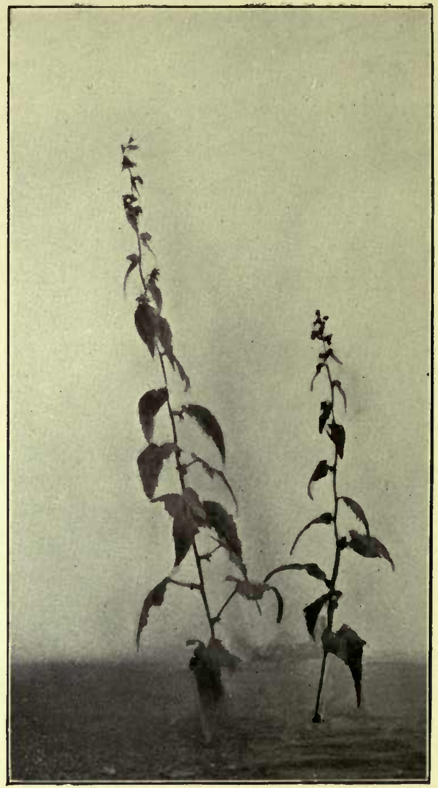


Photo by Miss C. Barnard.

Nettle-leaved Campanula.

To show leaves arranged on stems in such a way that light falls on all.

CHAPTER II

The Growth of the Shoot from the Bud

After the emergence of the cotyledons above ground, the first bud or plumule is to be seen between them. This is the germ of the shoot and it develops into stem and leaves. That the plumule does give rise to the stem and leaves may be ascertained, first, by watching the growth of the young seedling; and secondly, by examining the structure of the plumule. As soon as it appears above the cotyledons in a young seedling, it should be cut lengthways through the middle and examined with a hand lens. It will be found to consist of a central portion and of lateral outgrowths. This central portion is the stem; the lateral outgrowths are the leaves. All buds consist of these two parts, however variously modified the leaves may be.

Influence of Light.—The main function of the stem is to bear the leaves in such a way that they can obtain light, without which it is impossible for them to do their work. The first leaves of the seedling, the cotyledons, if they come above ground, are also dependent on light for the performance of their functions. In watching the growth of a seedling, it will be found, if accurate records are kept, that one of the most important factors in its development is not the intensity only of the light to which it is exposed, but even more the duration of the hours of sunshine each day. The intensity of light can be measured by an ordinary exposure meter such as photographers use, and the hours of sunshine are obtainable from meteorological offices.

The influence of light on colour is a matter of common experience. Any one who has watched a tree in the spring must have noticed that the buds as they unfold have yellowish-green leaves; the same thing is seen in seedlings. When the cotyle-

dons of the Radish first show above the surface they are yellow; so too are the plumules of the pea and bean. Then as the bud unfolds, a tinge of green appears; still, the prevailing tone is yellow rather than green for some days. Gradually the green deepens, and with the soft, tender green of the young stems and young leaves at the tips of the twigs, forming a refreshing contrast to the darker stems of the preceding year's growth, spring has come. It is a matter of experience that in some years spring is earlier than in others, and in those years there has generally been

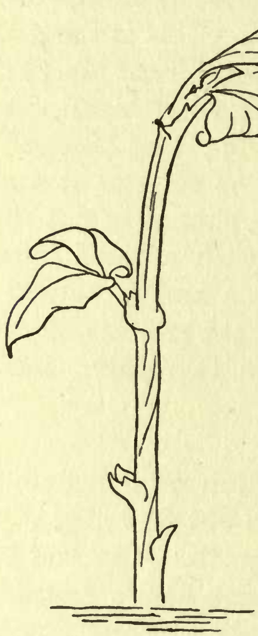


FIG. 17.—Bean plant grown in the dark.

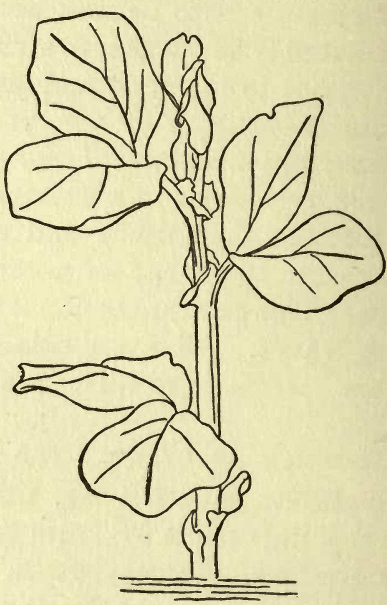


FIG. 18.—Bean plant grown in the light.

more sunlight. Putting these facts together, it seems clear that light is essential for the development of the green colouring matter of the leaf. It is easy to verify this by growing some seeds in the dark, and others of the same species in the light. Those grown in the dark produce cotyledons and foliage-leaves of very much the same yellow tint as the leaves of the buds of trees when they first begin to unfold, or of seedlings when they first come above the soil. The difference in the colour of the leaf is due to the absence of light. This affects not only the colour of the leaf, but that of the

flower. If two bulbs of the dark blue Hyacinth are grown in hyacinth glasses, one in the dark, the other in the light, the following differences may be seen :—

1. The leaves of the one are yellow; those of the other green.
2. The flowers of the one grown in the dark are paler.
3. The stem of the one grown in the light is upright, much shorter and able to bear the weight of the spike of flowers, whilst that of the one grown in the dark is straggling, inclined to fall down, much longer and unable to bear the weight of the inflorescence.

Exactly the same differences will be found in Nature. A Dead-nettle growing in the light has shorter internodes than one hidden in a hedge and more or less shaded from the light, and although it may not be easy to find plants with yellow leaves in a hedge, it is very usual to find them with much paler green leaves. The leaves of trees in a wood show the same differences. Those on the fringe of the wood are greener than those in the depth of the wood, and flowers carpeting a wood are often paler in the thickest part of the wood than on its outskirts. This is well seen in the Herb-Robert.

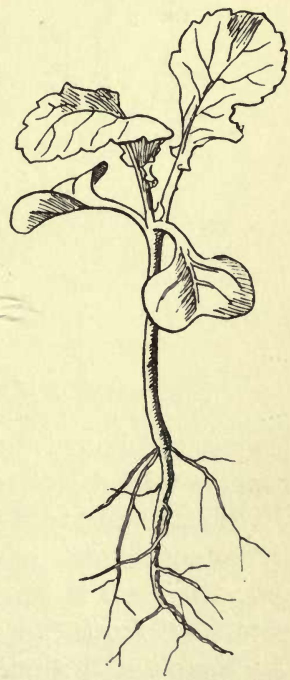


FIG. 19.—Seedling of Radish.

COMPARISON OF FOLIAGE-LEAVES WITH COTYLEDONS.—A little observation of seedlings soon shows that cotyledons are very varied. This great variety is due to several factors: the size of the seed, the presence or absence of endosperm, the manner of folding of the cotyledons in the seed, and, perhaps most of all, the shape of the seed. It is obvious that narrow cotyledons will fit best into long narrow seeds, as in the ash and sycamore, but there are very many instances of narrow seeds with broad cotyledons. In the latter, Lord Avebury points out that the cotyledons lie transversely to the seed, not lengthways as in the former case.

Cotyledons are folded very variously in different seeds. The long, narrow cotyledons of the Sycamore are applied face to face, rolled up in a ball, then as they emerge from the seed they unroll and spread out. With the Sycamore may be compared the Beech. The bracts forming the cup of the Beech-nut generally dehisce into four pieces, enclosing usually two fruits. In each fruit two ovules begin to be formed, but generally only one develops. The

FIG. 20.—Seedling of Sycamore and Beech, with cotyledons and foliage-leaves.

seed is not large, and the cotyledons are soon too big for it and become folded, not rolled up.

With regard to the presence of endosperm, it may be stated that if the cotyledons remain in the seed and do not come above the soil, the seed is generally exalbuminous, for the young seedling gets food from the cotyledons. These fill the whole seed, as in the Bean and Walnut.

Not only are the cotyledons of plants very different from each other, but they are very different from the foliage-leaves that follow. Here again the Beech and Sycamore may be compared. The

Sycamore has a large palmately lobed leaf, very different in size and shape from the narrow cotyledons; whilst the Beech has a simple, comparatively small undivided leaf, not very much larger than the cotyledons, and much less fleshy. The cotyledons of the Oak may be compared with its first leaves. The former are thick and fleshy and remain in the ground, whereas the first foliage-leaves are almost scale-like, particularly in the Evergreen Oak (*Quercus Ilex*), and then follow the well-known foliage-leaves with their sinuate margins.

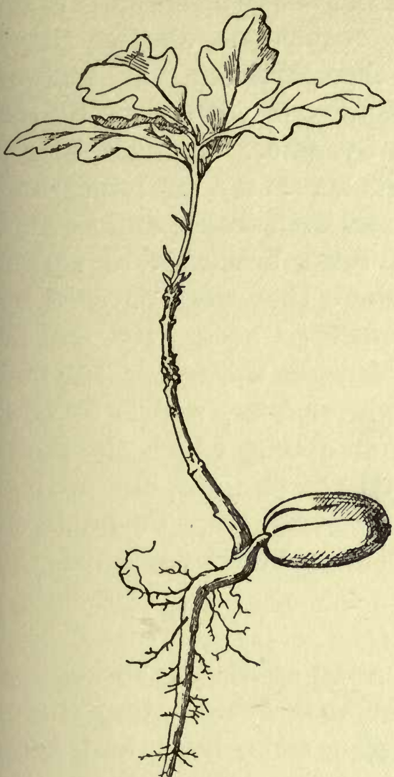


FIG. 21.—Seedling of Oak, two years old. Cotyledons enclosed in acorn.

Another very interesting seedling to observe from this point of view is the Gorse, usually found in May, or if it is an early spring in April. Very often not far from Gorse bushes, young buds may be seen on seedlings of Gorse, about 4 or 5 inches in height. If carefully observed it will be found that the cotyledons are deep green, rather fleshy, and about ½ inch long. As the stem develops from the plumule it is succulent, and the first leaves are either simple or trifoliate. Then the stem gets hard and woody and the later leaves become spiny. The branches arising in the axils have spinous leaves from the first.

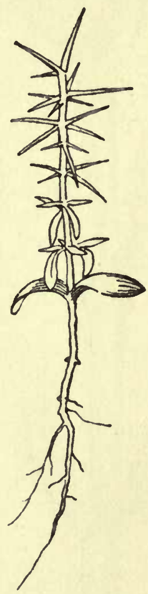


FIG. 22.—Seedling of Gorse. The foliage-leaves immediately above cotyledons are not spinous.

Many other instances could be given of the difference in cotyledons and foliage-leaves of the same plants; it is the

exception if there is any well-marked resemblance. The difficulty is to account for this very striking dissimilarity. Lord Avebury considers that the form of leaves depends largely on the shape of the buds, that of the cotyledons on the shape of the seed. Let us then examine the bud of the Sycamore and compare it with that of the Beech. The bud of a Sycamore is much bigger than that of a Beech, its leaves are far larger and more folded. It is covered with scales, and as soon as the buds begin to open hundreds of scales, green at the bottom where they were covered by outer scales, but brownish-red at the tip, will be seen on the ground underneath the tree. The bud of the Beech is long and slender, and is covered with brown stipules, from among which the green leaves appear. The leaves lie straight, and are less folded than those of the Sycamore. Certainly in this case the more slender bud does have the smaller leaf.

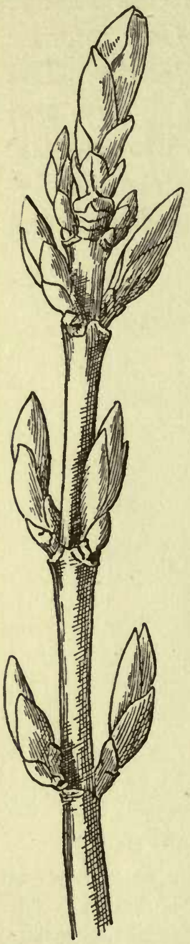


FIG. 23.—Twig of Sycamore buds just about to burst in spring.

BUDS.—The examination of trees in spring just as the buds begin to burst is a fascinating study. The best plan is to pick some buds and keep them in water in one's room to look at frequently during the day. The first interesting thing is to notice the position of buds. The accompanying figure of a twig of Sycamore shows an apical bud and axillary ones. It will be seen that the axillary ones all have the scar denoting the position of the fallen leaf-stalk under them. In this twig the internodes are long and the year's growth considerable; it is what is called a "long-shoot." The limit of the year's growth is marked by the scars left by the scales of last year's bud. Some twigs have much shorter internodes, then the shoots are "dwarf shoots," and the leaves are more or less tufted. The Beech and Ash show this very well. In examining buds, it is important to notice which bear flowers in addition to leaves, as this to some

extent affects the shape of the tree. In the Horse-chestnut the apical buds contain flowers, and as the formation of a flower stops growth in length, the Horse-chestnut is broad rather than tapering. The apical bud of the Ash, on the other hand, contains only leaves, the flowers being in the lateral buds. Compared with the Horse-chestnut, this is a more tapering tree.

In winter, buds are usually covered with bud-scales; in this way they are protected from cold and damp. In some cases, as in the Horse-chestnut, the bud scales are covered with resin, which give it a glistening appearance in the hot suns of an early March. Externally, where exposed to the light, the scales are brownish-red; where overlapping each other, they are greenish. After removing the scales the young green leaves in early spring are wrapped in down, and if the bud is an apical bud the floral leaves may be seen in the centre. All those leaves—scales, foliage, and floral-leaves—are borne on a stem-like portion. It is clear that a bud is the germ of a shoot, for it consists of a stem portion and of leaves.

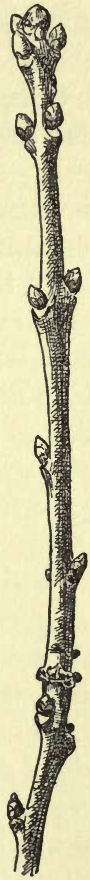


FIG. 24.—Twig of Sycamore in winter.

Trees may often be recognised in the winter not only by their bark, but by their buds. Those of the Horse-chestnut are dark brown, very large, and remarkably sticky from the resin on them. The Ash, as Tennyson notes, has olive-green, almost black, buds in spring—

"More black than ash-buds in the month of March."

The long, slender, light brown Beech buds are characteristic of the tree, and allow it to be distinguished at a distance from the Oak, with its stouter, shorter buds of a rich brown.

The Maple may also be distinguished from the Sycamore, to which it is closely allied, by the pinkish colour of its buds, which deepens into a beautiful red as the spring advances. The Alder is recognised by its purplish-brown scales.

STRUCTURE OF WINTER BUDS.—*Ash.*—Winter buds show a wonderful adaptation of structure to function. Their outer scales are developed from very different organs. Some are formed from the part of the leaf attached to the stem, the "leaf-base" as it is called; this is the case in the Ash, Horse-chestnut, Sycamore, and in most rosaceous trees. Or bud scales may represent stipules, structures which occur in pairs, as lateral branches of the leaf-base. The bud scales of the Oak, Beech, Poplar, Alder are modified stipules. In the Alder and Poplar the stipules are fewer than in the Oak and Beech. Again, bud-scales may represent true leaves, as in the Lilac and Honeysuckle. Some of these winter buds may now be examined more in detail. The bud of the Ash is covered by two or four thick, olive-green scales. These overlap and enclose the young leaves covered with down. In the apical bud, these young leaves are all foliage-leaves; in the axillary buds, both foliage and floral leaves are found. As a rule, one axillary bud develops into a branch; the opposite one into a flowering shoot. All these leaves, bud-scales, foliage, and floral-leaves are borne by a central structure, the stem. It is by means of the scales and the down that the young leaves are protected from the cold and damp of winter. The bud scales are of the nature of leaf-bases, for they show rudimentary leaves at the tip. The dark colour is due to a layer of flattened hairs, which secrete a resinous substance, that helps to protect the leaves from damp.

Horse-Chestnut.—The Horse-chestnut has almost the largest buds of any tree. Each is protected by eight or ten scales, and is very sticky owing to the resin secreted. To take off the scales without breaking them, the bud may first be dipped in methylated spirits. If all the scales are removed and placed side by side, the difference in colour and size is striking. The most external are dark brown and small; inside these come structures which are green and herbaceous, and within these are the true foliage-leaves, covered with down. Inside these foliage-leaves are the floral-leaves. All these sets of leaves are borne by a stem. This bud shows a gradual transition from bud scales on the outside, to true foliage-leaves, something intermediate between scales and leaves being present between the bud-scales

on the outside and the inner leaves. Such a series serves to indicate the nature of the bud scales. They are leaf bases, *i.e.* the bases of leaves which develop no upper parts or blades, but become hard and scaly as the buds form.

Sycamore.—The bud scales of the sycamore are tough and dark coloured, where exposed to the air and light ; the inner portions are paler. As a rule, the bud of the Sycamore has fourteen scales, arranged in two opposite rows of four each, and two intermediate rows of three each, but sometimes there are only twelve scales. Within the scales are two pairs of folded foliage-leaves. The structure of the bud-scales is best seen in spring when the bud is expanding and the scales are falling. They are long and narrow, and concave on the inner side so as to wrap round the bud. If the tip of each scale is examined with a lens, a small three- or five-lobed structure is seen, protected, almost hidden by a mass of brown hairs. This is a rudimentary leaf-blade ; the scale itself is therefore a leaf-base which has become greatly enlarged. Those Sycamore buds which contain flowers as well as foliage-leaves are larger and open earlier than the ones which have only foliage-leaves.

Oak.—The scales of the Oak are arranged in five rows, which are tightly folded over each other. They are arranged in pairs, as would be expected, because they are developed from stipules, which occur in pairs. There are sometimes as many as twenty pairs, each pair varying in shape and size. The lowest scales are small, the innermost are the largest. The edges are fringed with hairs, which drain away the moisture.

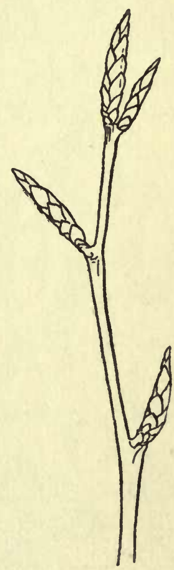


FIG. 25.—Twig of Beech in winter.

Beech.—The bud of the Beech resembles that of the Oak in having a large number of scales formed from stipules, some sixteen pairs altogether. The lowest pair is triangular, small, and pointed ; the next four or five pairs gradually increase in size and closely overlap each other. The part of each scale exposed to the weather is brown,

whilst the portion overlapped by the succeeding scale is white or greenish. The hairs of the scales are not black as in the Ash, but silvery. The foliage-leaves do not occur between the lowest stipules, but begin about the twelfth pair. In a bud just on the point of opening a folded foliage-leaf will be seen between each pair of stipules, from the twelfth upwards. The number of stipules and foliage-leaves varies in the different buds; the larger ones have more leaves and stipules than the smaller.

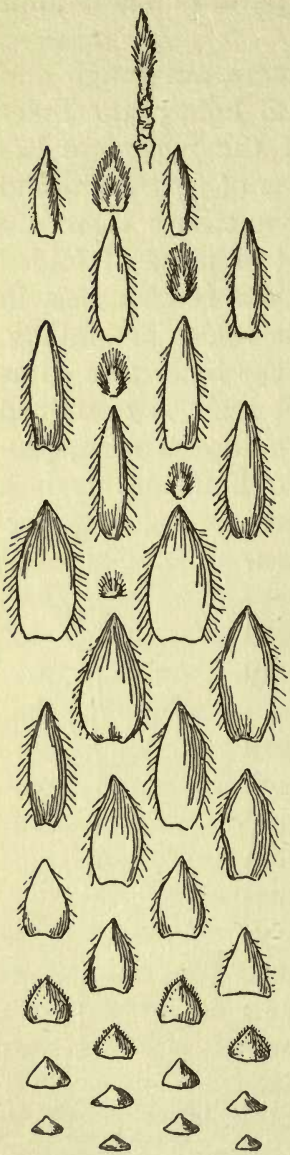


FIG. 26.—Bud of Beech with stipules removed.

The Black Poplar.—The terminal bud of the Black Poplar has from nine to ten pairs of stipules, the two lowest being the hardest. The foliage-leaves of the bud are first found between the third pair of stipules; in this tree the stipules are largely developed and gummy, in order to protect the foliage-leaves inside.

Lilac.—The terminal bud of the Lilac usually does not develop, its place being taken by two lateral buds. In this shrub the bud scales are small leaves, not enlarged leaf-bases as in the Sycamore. They are opposite each other, forming four rows, and are from six to ten in number. The scales gradually pass into ordinary leaves, and may be regarded, therefore, as modified leaf-blades. The bud-scales of Honeysuckle resemble those of Lilac in this respect.

The Coniferæ.—The bud-scales in a Pine may number one hundred, or even three hundred, in some species, and are arranged spirally. They are small and brown, and bear in their axils a small bud; each scale represents a whole leaf and not merely a leaf-base, or a leaf-blade.

The so-called "bud" is therefore not a single bud, containing either foliage or floral leaves, or both; it is a bud of buds, each true bud giving rise to a dwarf shoot, the buds which will give rise to long shoots being developed only in the axils of a very few of the numerous leaves. The outside scales have cork layers and resin is secreted, so that the shoots are well protected. Among the Coniferæ, bud-scales are found in the Pine, Spruce, and Yew, but the Juniper and Cypress have none.

NAKED BUDS.—Other examples of trees with "naked buds" as they are called, are the Wayfaring-tree, and the Alder Buckthorn. The evergreens of tropical climates are often destitute of bud scales. In most herbaceous plants the terminal bud is merely the end of the growing shoot, its covering is just an ordinary leaf, similar to any other.

Bud-scales are usually developed in those buds which pass through a period of resting during the winter. They protect the delicate leaves from the winter cold and wet, and prevent loss of water which would take place owing to the dryness of the air at a time when the tree would not be able to replace it.

The following classification of bud-scales, according to the organs from which they are formed, may be useful :—

1. Bud scales representing leaf-bases occur in Ash, Horse-chestnut, Sycamore, and most rosaceous trees.

2. Bud scales developed from stipules are found in Oak, Beech, Poplar, Alder.

3. Bud scales formed from true leaves in the Lilac and Honeysuckle.

4. Naked buds occur in the Alder Buckthorn, in some species of *Viburnum* (the Wayfaring-tree), in Juniper and Cypress, and in most evergreens, especially in tropical countries.

The way in which leaves are packed in a bud is a never-ceasing subject of wonder each year as spring comes round. It seems incredible that the large leaves, such as Sycamore and Maple; the compound leaves, consisting of several pairs of leaflets, of the Ash can be packed in such small space. The only way of seeing the relative arrangement of the leaves in a bud is to make a section and

look at it under the microscope. In the Ash, two compound leaves, each having seven leaflets, will be seen in the centre opposite each other. The next two leaves are at right angles to those, the next two to the second pair, and so on until the four outer scales are reached. The accompanying figure shows the arrangement in the bud of the Sycamore.

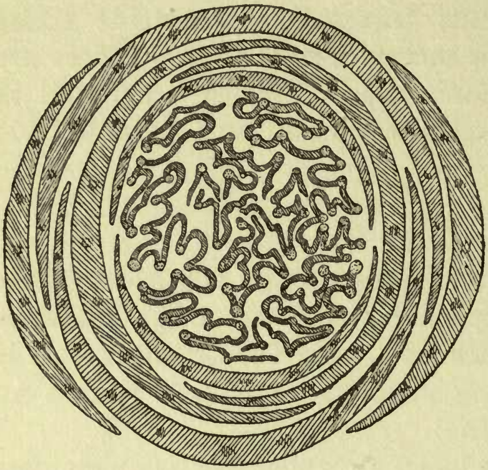


FIG. 27.—Bud of Sycamore, transverse section. Bud scales on the outside, and foliage leaves in the centre.

In spring, as soon as the scales burst and the foliage begins to open out, the internodes of the stem grow longer and longer, giving rise to the "long-shoots" at the apex of the twig. As the shoot elongates, buds begin to be formed in the axil of the leaves. Towards the end of the summer these buds may be seen, and when the leaf falls off in the autumn, leaving its scar behind it, the buds are prominent. In the following spring the apical or the topmost lateral bud develops into the new shoot. Meanwhile in the winter it is protected from wet and cold by the scales, downy hairs, resin, etc., already mentioned.

ADVENTITIOUS BUDS.—Sometimes buds develop without any definite relation to the leaves; these are called "adventitious"; they are, as it were, accidental or accessory. The buds that appear on the wounded edges of a begonia leaf when it is sliced and pinned down on damp sand, is a case in point. Under abnormal circumstances buds may develop even on roots and give rise to leafy or even flowering shoots, as in the Hawthorn.

The study of buds affords considerable material for practical work. About March or April, or even earlier, twigs of different trees may be examined and the position of the buds noted. Then the nature of each bud should be determined, whether it will

give rise to a leafy or to a flowering shoot. The character of the bud scales, the organs from which they are formed, and the means by which they protect the inside tissues should be investigated, and sketches made of the different structures, with the date of observation. Then as the buds begin to burst and the leaves and flowers come out, the buds should be examined again, and the later stages of growth compared with the earlier ones. It is a good plan to watch the gradual opening of the bud and unfolding of the leaves from day to day. The way in which the leaves are packed in the bud should be noticed.

In gardening, the effect of pruning will be found to cause buds to develop which would not otherwise do so. The structure of such buds, as those of Cabbage and Brussels Sprouts, may be compared with the buds of shrubs and trees.

BRANCHING.—The branching of a stem depends on the position of the buds and on which buds develop. As buds are situated in the angle which the leaf makes with the stem, the branching of a tree would normally follow the arrangement of the leaves. All buds, however, do not develop, for if they did the shoots would become overcrowded and would not get enough light. In the elms, lime, and some other dicotyledons, the terminal bud is suppressed and the axillary bud beneath it then swells and takes its place. In such stems, the main trunk consists of a series of branches. In time, the lower ones drop off; the bare portion of the trunk is then known as the "bole," while the mass of boughs, branches, and foliage above it, is called the crown.

Another factor affecting the development of the branches is the relative position of the leaf and flower buds. In some trees, the terminal buds develop into leafy shoots. This is the case in the Ash. In others, the terminal bud contains the flowers, as in the Horse-chestnut, and growth is continued by the lateral buds. This partly accounts for the difference in the shape of these two trees; the Ash, as we have seen, is more tapering than the Horse-chestnut, which has its upward growth stopped, in some branches at any rate, by the formation of the flower.

The branching of one or two trees may be noted in detail. In the Oak, the terminal bud is a leaf bud with lateral ones clustered round it, just as the leaves are. The branching is tufted or rosette-like, the branches being apt to turn and zigzag from side to side. If a Beech is growing in the open, the branching may begin very low down. Sometimes the bole divides into several trunks, each giving rise to a full-grown tree. When growing in a dense forest, the branches may not begin below a height of 60 feet. They are usually developed from "long-shoots" and are often horizontal. They afford considerable shade, and without the beech, it has been said, many timber trees would have to be given up; on the other hand, herbaceous plants do not thrive under it, no doubt from want of sufficient light. In summer, its undergrowth consists mainly of parasitic plants, such as the Bird's-nest Orchis, Toothwort, Broomrape, etc.

Some trees and shrubs do not develop terminal buds at all, as the Elm and the Lilac; in these growth takes place from lateral buds. In the Elm the branches are some considerable height above the ground. It often forms hedges, on account of its habit of throwing up suckers, and other plants thrive well under it.

Few objects are better suited for the purpose of cultivating the power of observation more than trees. To be able to recognise a tree at a distance and at any season of the year is only possible to those who have a very real knowledge of its growth. The branching is best seen in winter, when it lies stripped and bare. The height from the ground at which the lowest branches are given off, the angle they form with the main trunk, their general direction, the downward or upward bend of their twigs must all be known before the tree can be recognised with any certainty. Then there is the bark, so characteristic a feature of the tree, and the shape and colour of its winter buds, and in spring and summer the endless variety of foliage—all affording material for the observation of a lifetime.

THE WORK OF LEAVES.—The work of leaves is very varied, and some of it cannot be carried on without light. The necessity

of light accounts for the great variety in the arrangement of leaves or stems. In temperate regions, where light is often diffuse and always less intense than in tropical regions, the blade of the leaf is usually spread out to the light, and one leaf must not be exactly above another. The arrangement of leaves on the stem may easily be observed in some of our common plants. In the Dead-nettle, the leaves are two opposite each other ; the next pair of leaves is not on the same sides of the stem as those immediately below or above them, but on the other two sides, and in this way the lower ones are not deprived of light by those above. The best way of obtaining some idea of the very varied arrangement of leaves is to examine several plants and to notice that those leaves which may be said to lie almost exactly above each other are borne by the stem at some distance from each other, and there may be two, three, six, eight, or even as many as eleven leaves between those which are situated immediately above each other. Teachers may suggest, as a lesson in observation, the finding plants in which the leaves are arranged in at least six different ways.

(i.) Carbon Assimilation.—Light is essential for the development of chlorophyll. That it is the chlorophyll which is concerned in the work of carbon assimilation may be easily demonstrated, but even when chlorophyll is present, leaves will not assimilate carbon except under the influence of light. The fact that carbon assimilation is going on in a leaf generally shows itself in the formation of starch. When starch is present in a leaf, carbon must have been assimilated, for carbon is one of the constituents of starch. Green leaves are always making starch in sunlight, and it is easy at any moment to find out whether starch is present in a leaf. Boil it in a test-tube, then place it in methylated spirits to get out the green colour, in order that the starch may be more easily seen. As soon as the leaf looks colourless, place it in iodine, and if starch is present the leaf will become dark blue. Instead of taking a green leaf, a variegated leaf may be chosen and tested with iodine ; the leaf of the variegated Ivy will do. The green part of the leaf becomes dark blue, the rest does not. This little experiment shows that

it is the green colouring matter, the chlorophyll, which makes starch.

Another experiment that any one can try is to cover up the leaf of a plant with tinfoil for about twenty-four hours and then to test for starch with iodine, as just described. Or plants may be grown in the dark and the iodine test applied. It will invariably be found that when excluded from light, starch is not formed, because the chlorophyll has not been able to do its work.

The chlorophyll is present in the form of small corpuscles in all the cells of the leaf except in the thin skin or epidermis on each side. The structure of a leaf is seen in Fig. 28.

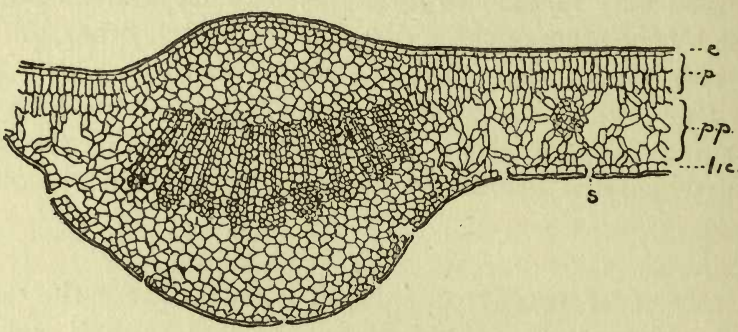


FIG. 28.—Transverse section through leaf-blade. *e*, epidermis; *p*, cells containing chlorophyll; *pp*, cells with chlorophyll and intercellular spaces; *le*, lower epidermis; *s*, stomate.

This was drawn under a low power of the microscope, and does not show the grains, but merely the layers of cells, forming the thickness of the leaf. Near the upper surface, two rows of cells may be seen without any spaces between them, whilst the other layers have spaces. It follows that the upper face of the leaf will be darker in colour than the lower, because the chlorophyll is greatest in quantity there. The majority of leaves have a darker upper surface and a lighter under surface owing to this arrangement of the chlorophyll. There are some plants, however, with leaves of the same colour throughout, owing to the absence of these two rows of cells without intercellular spaces; the chlorophyll is evenly distributed, and the leaf is yellowish rather than green, as in the Stonecrop.

In order that the chlorophyll may do its work, the plant must be supplied with carbon dioxide. This gas is always being breathed out by plants and animals, so that there is always some in the air. If it is prevented gaining access to the plant, starch cannot be made. To demonstrate this, a pot containing a green plant—clover does very well—should be placed under a bell-jar. By the side of the plant a small bottle containing a strong solution of caustic potash should be placed, to absorb the carbon dioxide given off by the plant. Through the india-rubber cork of the bell-jar a bent glass tube is passed. The U-portion of the tube is filled with soda of lime, which absorbs the carbon dioxide from the air passing through it into the bell-jar. Thus no carbon dioxide reaches the plant. After about twenty-four hours the leaves of the plant may be tested, and will be found not to turn blue when soaked in iodine. In trying experiments connected with carbon assimilation it is always best to leave the plant in the dark a day or so before beginning the experiment, in order that any starch then the present in the leaf may be withdrawn from the leaves through stem to the root or the other part of the plant.

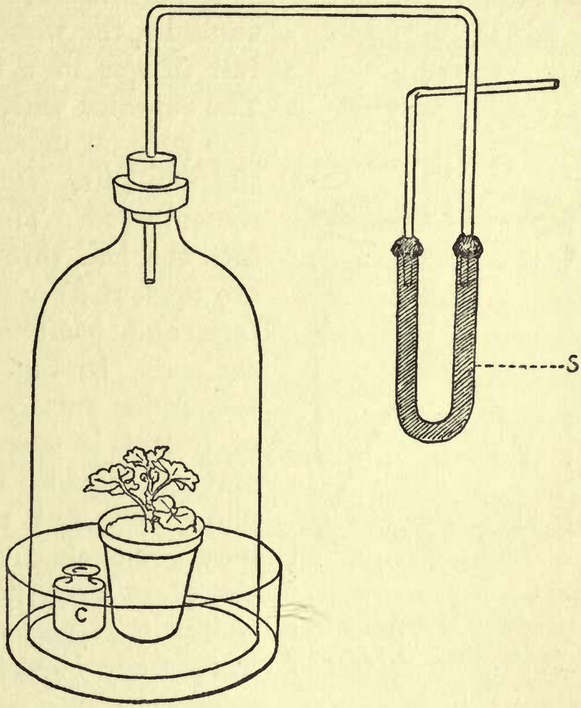


FIG. 29.—Apparatus for excluding carbon dioxide. S, soda of lime. C, caustic potash.

The work of the chlorophyll is to separate the carbon from the carbon dioxide. With the carbon thus obtained and with water from the roots starch is made. The oxygen of the carbon dioxide is returned to the air ; for it is the carbon alone that the

chlorophyll " fixes," as it is said. That oxygen is given off by a plant engaged in carbon assimilation is easily shown on a bright sunny day. The experiment is best tried with a water-plant such as Elodea. The plant should be placed in a glass jar of water under a funnel. Over the funnel, invert a test-tube full of water, holding it under the water whilst placing it in position. If the light is intense enough, in less than an hour bubbles of gas will be seen passing up from the plant and collecting at the top of the test-tube. In fact, if the apparatus is placed on a lawn in bright sunlight, the whole test-tube may become full of gas in a couple of hours or so. The rapidity with which carbon assimilation goes on depends on the intensity of the sunlight. One more thing must be remembered. The carbon dioxide is taken into the leaf through the stomata which are present in numbers on the under surface and sometimes also on the upper surface. In Fig. 28 they will be seen on the under surface. If the under surface of a leaf is smeared with vaseline, the carbon dioxide cannot enter and the plant does not make starch. Stomata may get choked up with dust, and then the plant does not thrive. This is the reason that palms kept indoors ought to have their leaves washed about once a week.

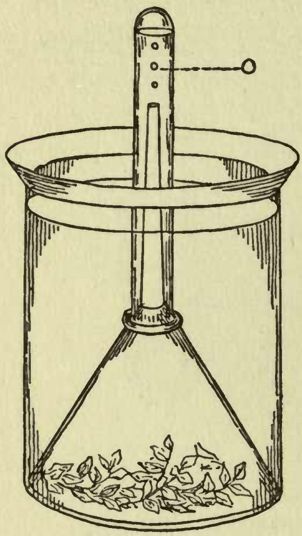


FIG. 30.—Apparatus to show evolution of oxygen during assimilation. O, bubbles of oxygen.

Starch grains are solid bodies, insoluble in water. These solid grains cannot pass through the cell walls, therefore the starch is converted into a soluble substance of the nature of sugar, and can then pass through the cells of the stem into the root, or underground stem, where it is stored up. The carrot and potato are instances of this. The grains of the cereals, wheat, rice, maize, all have a good deal of starch in them.

By the seaside or in sandy situations, plants will be found with very much reduced leaves, sometimes with none at all. In these cases, a couple of rows of cells will be found under the

epidermis of the stem. These cells closely resemble those of the leaf, they are full of chlorophyll grains, and carry on the work of carbon assimilation. The Marsh Samphire or Glasswort has no leaves, whilst Saltwort has very much reduced leaves.

(ii.) Transpiration.—Leaves are not only engaged in carbon assimilation, but also in transpiration. Land plants that live in the medium of our atmosphere are constantly having water pulled from them by the atmosphere. This is made good by the power of absorbing water which the roots possess, as already described in the last chapter. This water passes off into the atmosphere from the surface of the leaf. Every one knows by experience that one of the first signs of withering in a plant is the drooping of the leaf; watering the roots, if done in time, allows the plant to recover.

One of the simplest experiments, showing that water passes off from the leaf surface is to put some ivy leaves with their long stalks through a piece of cardboard into a tumbler full of water; on the top of the cardboard place a dry tumbler of the same size over the blades of the leaf. In a few hours, drops of water will collect on the sides of the tumbler and the water in the lower tumbler will gradually lessen. This is always happening in a dry atmosphere. When the air is laden with moisture, the leaves give off little, if any, water. Yet it is in dry situations that it is important for the plant to retain as much water as possible. The leaf has various contrivances for securing this. It may have a very thick skin, as in the Holly; it may be very hairy, as in the Hawkweed, Crepis, and many other Composites growing on hills, or it may curl up so as to shelter the stomata (see Fig. 28) completely, and thus prevent the giving off of water from its surface. There is a certain relation between the shape of leaves and the dryness of the situation. The Conifers are characteristic of dry soils; their leaves are very much reduced and acicular in form; the Heaths, the Acacias of Australia, the Gorse, the Cacti are instances of plants belonging to dry situations and having very much reduced and often spiny leaves.

Plants living submerged in water hardly transpire at all, and do not have water conducted through them, as in land plants.

In order to determine the exact amount of water lost by plants in transpiration, experiments may be tried with two sets of plants, one set being allowed to grow under the ordinary conditions in the greenhouse, whilst the plants of the second set, of the same species as those in the greenhouse, and as far as possible the same size and age, are kept in an experimental greenhouse under conditions that can be controlled. In an actual experiment conducted in this way, the amount of water transpired was determined by weighing, and special precautions were taken to prevent loss of water through evaporation. The result of the experiments has been thus recorded: "There are two daily extremes, a maximum loss around noon when the sunlight is most intense, heat usually the greatest, moisture least in the atmosphere, but a good supply of water in the soil around the roots; the minimum loss occurs some time during the night when the temperature is low, the atmospheric pressure approaches saturation, the darkness is complete, and in most plants the stomata are closed." The figures given showed that the amount of water transpired is about five times as much on the average per hour per square metre by day as by night. Another important fact brought out by such experiments is the extreme sensitiveness of transpiration to even slight changes in external conditions. The plants which are well adapted for class experiments are *Chrysanthemum frutescens*, *Tropæolum majus*, and several species of Pelargoniums.

It is interesting to inquire by what tissues the water travels through a plant. If a young twig with the cortex stripped off between two leaves is fixed in a cork, so that the cut end dips into a jar containing water, it will be found that the twig does not wither; the leaves remain spread out and do not droop, as they would do if they were not supplied with water. Clearly the water is not travelling along the cortex of the stem. In order to find out along which tissue it does travel, red ink may be added to the water, and after some hours, sections of the stem should be cut. The woody part of the stem is stained. The water travels along the wood. This tissue can be recognised with the naked eye, and looks like white lines. With care it can be traced from one internode to another, in such plants as the Dead-nettle.

It is because a plant is constantly giving out water that it is necessary to water it regularly. Young gardeners generally give too much water. It is important not to over-water, especially in frosty weather, but in warm weather, when evaporation is going on rapidly, water is necessary. As a rule, it is best not to water unless sufficient water can be given; surface watering does more harm than good. Too much water rots the roots, for this reason it is bad to leave pot plants standing in water day after day.

(iii.) RESPIRATION.—Although all the parts of a plant respire, the leaves are specially concerned in this work. Air enters through the thin cuticle when the leaf is young, through the stomata when the cuticle gets thicker, and carbon dioxide is got rid of by the same channels.

Through their manifold work of carbon assimilation, transpiration, and respiration, leaves profoundly affect the atmosphere around them. All visitors to the seaside know what a difference trees make to their enjoyment of the place; it is the drawback of some of our resorts that one is exposed to the glare of a pitiless sun without the shade of the green foliage so restful to the eye. Leaves prevent that dryness of the atmosphere which may become unpleasant, from the fact that water is being given out by them. Trees, too, attract clouds laden with moisture, and thus may be the means of securing moisture in a dry region; it is a well-known fact that the cutting down of forests, or even the thinning of trees in a garden, will make a difference to the degree of dampness of a house. Leaves also help to purify the atmosphere, for they need the carbon dioxide which is being constantly breathed out by all living things. When it is remembered that in this country our parks, meadows, pastures are carpeted with millions of blades of grass all using carbon dioxide under the influence of sunlight, and that the leaves of all our herbs, shrubs, and trees are also doing the same thing, it is hardly possible to overestimate the beneficial work done by leaves in keeping the atmosphere fit to breathe. Not only are they using the carbon dioxide of the air, but they are returning to the atmosphere the oxygen which has been separated from the carbon.

(iv.) Climbing.—Some plants climb by twisting their leaf-stalks round any object with which they come in contact. The Garden Nasturtium (*Tropæolum*) and the Clematis are the best known instances of this. It is this power of climbing that helps the Clematis to reach the luxuriance it does in Gloucestershire and Somersetshire, although something too depends on the soil. Many of the Leguminosæ develop tendrils in the place of leaflets for the same purpose, *e.g.* the Peas, the Vetches.

Classification of Leaves.—So far foliage leaves have been the most fully discussed. In botanical language, however, the term "leaf" includes not only foliage-leaves but also seed-leaves or cotyledons; bud scales and the bracts which protect flowers; floral-leaves, namely, sepals, petals, stamens, and carpels. It was Goethe who first saw the identity of origin amidst this diversity of structure. In his treatise on *The Metamorphosis of Plants*, written in 1790, he shows that all these structures stand in the same relation to the stem, they are all developed laterally from it. This generalisation gave the impetus to other similar researches, hence hairs and prickles being developed from the epidermis are now regarded as structures analogous to each other. Similarly, in the animal world, the fur of the rabbit, the scales of fishes, the feathers of birds, being alike in origin, are equivalent to each other morphologically, although the function of each is very different. Enough has already been said about cotyledons and bud scales, but not about the bracts which form the involucre of flowers, or of inflorescences. In the Compositæ, the minute florets are protected by bracts which overlap each other and are often fringed with hairs that conduct the water down from the bud. In this order, some arrangement of the kind is necessary, for the sepals of the flowers are very much reduced, and instead of protecting the essential organs of the flower, they become an organ of dispersion. These flower-heads of the Compositæ often close at night or in wet weather, then the bracts are erect, completely enclosing the florets; when the flower-heads are open, the bracts are more spread out, allowing the flowers to expand. Linnæus observed that the Dandelion opened from five to six in the morning and closed some time between eight and ten, that the Goat's Beard or John-

go-to-bed-at-noon opened from three to five in the morning and closed from eight to ten; the Mouse-ear Hawkweed, he says, is open in fine weather from seven in the morning until three in the afternoon.

Another order, in which an involucre of bracts is often though not always found, is the Umbelliferæ. One of the most beautiful species is *Astrantia*, in which the bracts are white and shining, looking silvery in the sunlight; they are far larger than the flowers themselves. In the Sea Holly the bracts are also coloured and conspicuous. When the wild carrot is in bud, the long green bracts arching over the umbel, form a great protection for the young flowers. In the Arum (lords and ladies) the conspicuous bract (Fig. 44) forms a chamber in which the flowers are situated and to which insects are enticed. Many hothouse plants, natives of tropical regions, have very conspicuous coloured bracts. The Poinsettia and the Bougainvillea are plants growing in the open air in the tropics, they are commonly seen at flower shows in this country; the one has a large leaflike scarlet bract, the other purple bracts forming a cup around the flower.

The observations that may be made on leaves are practically unending, only a few can be indicated here.

(*a*) The arrangement of leaves, whether radical or cauline. If the latter, whether they are spread out to the light, or merely present their edge to the sun's rays. Again, their relative position to each other, so as to secure light.

(*b*) The endless variety of shape, and the connection of this with the habitat of the plant.

(*c*) The general structure of the leaf; note any marked difference between the two sides, one much darker than the other. See whether leaves in which the chlorophyll is evenly distributed are connected with any particular habitat, as Stonecrop with dry situations. Make notes on the habitat of plants with hairy leaves, or leaves that roll in to protect the stomata. These will often be found in grasses growing by the sea.

(*d*) The difference in bud-scales of different trees and different herbaceous plants may be noticed. The scales of the winter buds of trees are particularly interesting.

(*e*) The sensitiveness of leaves, *e.g.* Wood-Sorrel, Mimosa.

The movements of the wood-sorrel leaves have been thoroughly investigated by Darwin and other botanists. Darwin also describes in detail the sleep movements common to many Lupines. "The shorter leaflets," he says, "which generally face the centre of the plant, sink at night, whilst the longer ones on the opposite side rise, the intermediate and lateral ones merely twisting on their own axis." Other plants with sleep movements are Melilot, Clover, Lotus, Mimosa. In fact, it may almost be said that sleep movements are specially characteristic of the Leguminosæ.

Pfeffer has devised methods by which leaves register their own movements. The records show not only the sleep movements, but the automatic movements which often accompany them. He found that under constant conditions the sleep movements disappeared in from three to five days, but automatic movements of much shorter rhythm continued independently of the sleep movements.

(*f*) The difference in cotyledons. To find cotyledons of shrubs and trees, look in the humus of woods, under and around the tree or shrub, in the months of April and May. Very often the cotyledons will be seen pushing their way through the dead leaves; it will often be possible to find some when at the first glance there may appear to be none, by scraping away some of the upper layers of the leaves.

THE WORK OF THE STEM.—The main work of the stem is to minister to the leaves.

1. The stem bears the leaves in such a way that they can all get light which, as we have seen, is necessary for the performance of some of their functions.

2. It conducts food to the leaves. The woody tissue in the root is continuous with that of the stem. By root-pressure water with mineral salts dissolved in it is forced into the wood of the root, thence it travels the whole length of the stem, to the leaf-stalk and veins of the leaf.

3. The stem conducts food from the leaves to the root. The starch made by the leaf is converted into sugar and passes, mostly by the outside cells of the stem, down to the root, where it is stored

up either in the form of sugar, or it may be reconverted into starch.

If the stems of plants growing in a hedge are compared with each other, great variety will be found. Some will be green and slender, others will be yellowish-brown, and a third set may have the power of twining. The green stems in all probability belong to plants that are annuals, *i.e.* they grow up, bear leaves, form flowers and fruit, then die down at the end of the season. Such a plant has no great weight of leaves to bear, and therefore can manage with a slender stem; it has to make food as rapidly as possible, and for this reason chlorophyll, which gives the green colour, is necessary to it. Further, as the plant dies down in the autumn the stem will not be exposed to the cold and damp of winter, and therefore needs no protection. The case is different with biennials. They do not produce seed until the second season, and therefore have to face the winter cold. Underneath the thin skin of the stem, a layer of cork is formed. This protects the underlying tissues, and may be recognised by its yellowish colour. Some plants are perennials. Their stems remain above ground several years, and go on increasing in thickness. These plants often have branched stems, because it is the only way in which they can get enough light for their leaves. A branch always arises, as we have already seen, in the angle which the leaf makes with the stem. This is shown very clearly in the accompanying illustration, which is magnified about fifty times. It also shows the layer of cork developed at the base of the leaf-stalk in the autumn. As soon as this is formed the cell sap from the stem cannot get to the leaf, which, deprived of nourishment, dies.

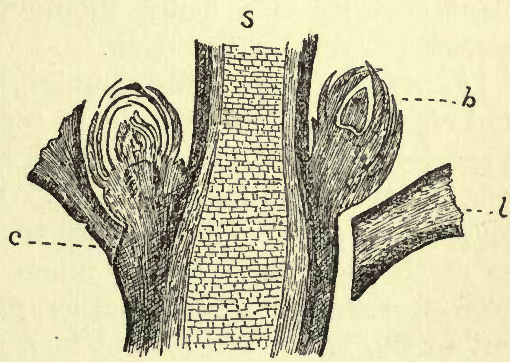


FIG. 31.—Section through stem and axillary buds. *s*, stem; *l*, leaf; *b*, bud; *c*, layer of cork.

Plants growing in hedges often have twining stems. The Black Bryony is one of the commonest. At the bottom of a

hedge it is often found twisting round a grass, then the tip of the stem may hang in the air for a while, until it catches hold of some other plant, and both together will climb up the Hawthorn, of which the hedge is composed, until they reach the top, where they can get the light. The Black Bryony must not be confused with the White Bryony, which is also a climbing plant. This latter has tendrils and very different leaves from the former. The Hop and the Convolvulus are instances of plants with twining stems, each in a different direction from the other. Scarlet Runners or Kidney Beans may be observed in any kitchen garden. In order to see how stems twine, the following easy experiment may be tried. Plant some Kidney Beans in a pot, and when the shoot has grown to about a foot in length, tie the stem to a stick 8 inches high. This will leave some 4 inches of the stem hanging over. This will revolve. Place a sheet of paper underneath the pot, make a dot to represent the tip of the stem at regular intervals ; in this way a tracing of the movement of the stem will be obtained. That plants climb by their leaves has already been discussed.

The effect of light on the growth of a stem is varied.

1. If exposed to light on all sides, the internodes are shorter than they would be if the plant has been deprived of light. A plant growing in a hedge should be compared with the same species growing in the open.

2. Stems, not naturally climbing, sometimes are very much bent and curved in their struggle to reach the light. On 29th July a species of Campanula growing in a high hedge on the sheltered side of the road was gathered. The stem had no less than four bends and curves, owing to the attempts it had made to reach the light. It was much entangled with other plants growing round one, then another, until its purple blossoms stood out to the light. Ferns kept in a room often bend towards the window.

Conclusion.—The adaptation of structure to function is very striking in both stem and leaf. The best way of realising this is to observe plants in their natural habitats as far as possible ; this can easily be done by those living in the country. They can

observe hedges, noting the difference in annuals and biennials; or they can climb some hill and compare the stunted growth of the herbs at the top of the hill with the more luxuriant vegetation of the valley below. In winter they can note the manner in which the buds are protected, and in the spring the folding of leaves in the bud.

Students that live in towns may do much with a small garden. Climbing plants may be observed in the Nasturtium, Scarlet Runner, or Kidney Bean; buds in such shrubs as the Lilac or the Laburnum; the stem of the biennial Wallflower may be compared with that of a perennial Sunflower. Simple experiments, such as those indicated, may be tried by any one who has the necessary patience, and experiments help in the interpretation of Nature. In teaching, the important thing is to plan the experiments so that they succeed each other in a right order, the one following naturally on the other. The best time of year for experiments on the life and growth of plants is undoubtedly the spring, because the vital activity of the plant is then specially great; but even in the autumn and winter a great deal can be done, provided care be taken to secure a right temperature.

CHAPTER III

The Growth of Plants independently of Seeds

Many plants propagate themselves independently of seeds. This is especially the case in cultivated plants, like the Sugar-cane, the Potato, the Begonia, and the Geranium. Plants which are not indigenous to a country often take a long time to mature and do not make seed freely; it is an advantage to such plants to be able to multiply independently of seed production. At the same time it must be remembered that a plant propagating itself independently in this way may in time become worn out. The most striking instance of this is the sugar-cane, which has been grown for some two thousand years by "suckers" springing from the original stem. In Barbados, where the Bourbon cane was the species chiefly cultivated, attempts are being made to grow other species. In this country, the potato is said to be less strong than it used to be, and new varieties are being introduced, or seedlings are grown in order to get a stronger plant than is the case where tubers alone are cultivated. Seeds, too, are used when new varieties are being sought. Many wild plants are also propagated without forming seed, as it is an advantage to a plant to have two means of multiplying itself, for there is great loss of life where seeds are concerned. They may be eaten, they may fall on hard ground, they may die through exposure to cold, they may rot from damp. Even where seedlings are produced, a large number must perish; they may choke each other, they are eagerly devoured by grazing animals, and young seedlings are peculiarly susceptible to changes in weather and particularly to extremes of heat and cold.

Methods of Self-Propagation.—(i.) *By creeping stems.*—One of the most common of our buttercups (*Ranunculus repens*) multiplies in this way. The stem creeps along, rooting at the

nodes, and as the internodes decay, a new plant is formed at each node that has developed adventitious roots. This is one of the most prolific of the Meadow Buttercups, and is therefore easily observed. The Ground Ivy, very common in hedges, propagates itself in a similar way. Two weeds that are very troublesome to the farmer, and which would cover large areas of ground if left alone, spread in this way, namely, the Creeping Plume Thistle and the Couch-Grass. It is no use cutting off the heads of the thistle, as the underground stem is perennial and creeps along underneath the ground. The couch-grass forms buds in the axils of the leaf-sheaths, the buds burst through the sheath and run horizontally as underground stems, called stolons. These root as they creep along, forming new plants at each rooting. Although some grasses are a nuisance to the farmer, others are of value, especially on sandy shores. The two most important are the Sea Mat-Grass (*Psamma arenaria*) and the Sand Lyme Grass (*Elymus arenarius*). Neither of these is of any use as fodder, but they bind sand together, and help to build up sand-dunes. This is very well seen at a place like Newbiggin-on-Sea, not far from Newcastle. The sand on the seashore is blown about by the wind, and may be described as shifting sand; here the grasses begin their work of binding, and a few yards inland the shifting sand gives place to a region of firmer sand, where sand-dunes are being formed. In passing, it may be mentioned that the vegetation of the shifting sand area is far more scanty than that of the firmer region, for until the grasses have done their work, it is impossible for many other plants to get a sufficient depth of soil in which to grow.

The common Cinquefoil (*Potentilla reptans*), which is found in most hedges and on waste ground, has stolons with long internodes. On examining these stolons, it will be found that each is made up of a number of branches, for at each node there is a reduced leaf, in the angle of which a new stolon-branch originates; each new branch continues the direction of growth of the preceding branch, giving the appearance of one long continuous stolon.

This creeping habit of plants has been made use of in cultivation. The Solomon's Seal and Iris of our gardens are perpetuated

by means of creeping underground stems. In Fig. 32 the nodes (*n*) of the underground stem of Solomon's Seal from which the roots are given off are well marked; the internodes (*int*) are very short, because the nodes are crowded together. The new plant arises from the bud (*b*). The leaf-scars, showing the position of the leaves, are shaded. These leaves are scale-leaves and protect the tip of the growing stem. They must not be confused with the green foliage-leaves, which are borne on the aerial, and not on the underground stem. The underground stem of the Iris very closely resembles that of Solomon's Seal. It is fleshy, and bears parallel leaf-scars, but in this plant the leaf-scars represent the basis of the foliage-leaves. Both these plants come up in larger clumps year by year, and new plants are easily obtained from them by the process of separation.

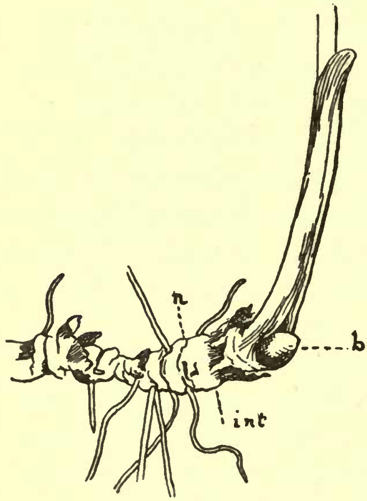


FIG. 32.—Underground stem, Solomon's Seal. *n*, node; *int*, internode; *b*, bud.

Strawberries are propagated by stems creeping along above the ground. These stems are called runners, and grow out in the axils of the main plant. That they are stems is clear, because they bear small leaves and end in buds. From these buds foliage-leaves arise, and at the base of the bud roots are developed, thus a separate plant is formed. This plant in its turn may become the parent of others, by producing runners.

With the Strawberry may be compared the Gooseberry. The branches of this latter plant bend down, roots are formed at the end of the branches, which become detached and form independent plants. The suckers of Raspberries are also of the nature of stems.

(ii.) *By bulbs.*—A bulb consists of a short conical stem portion, and of leaf-structures borne by the stem. These latter occupy the greater part of the bulb. In some bulbs the leaf-structures are merely the basal portions of green leaves, the blades of which

have withered. In the Snowdrop, the bulb consists of a short stem portion, which bears two scaly leaves. These are the bases of the two green foliage-leaves of the snowdrop plant. Many bulbs have scale-leaves on the outside; foliage-leaves within these; floral-leaves in the centre. All these sets of leaves are borne by the short stem. The accompanying illustration is a medium vertical section of a Narcissus bulb, showing the scale-leaves (*sc*) on the outside, within these the foliage-leaves, and in the centre the floral-leaves (*f*).

Onions and Shallots are bulbs commonly grown in kitchen gardens. Onion seed, sown the end of February or early in March, will produce young onions for salad by June. If wanted for the winter they should be disturbed as little as possible, though care should be taken to keep the ground free from weeds. When the bulbs are fit to gather they should be laid out on an open piece of ground, where they will dry and harden; they should be turned two or three times a week, and when thoroughly dried stored for the winter.

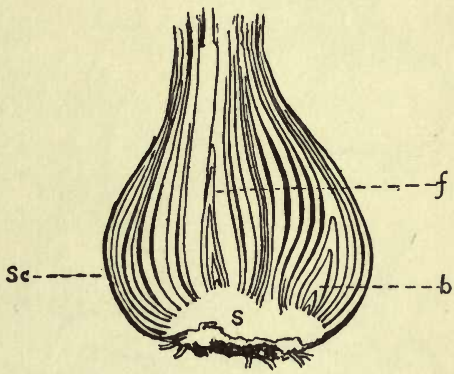


FIG. 33.—Median vertical section of Narcissus bulb. *sc*, scale-leaves; *f*, floral-leaves; *b*, bud; *s*, stem.

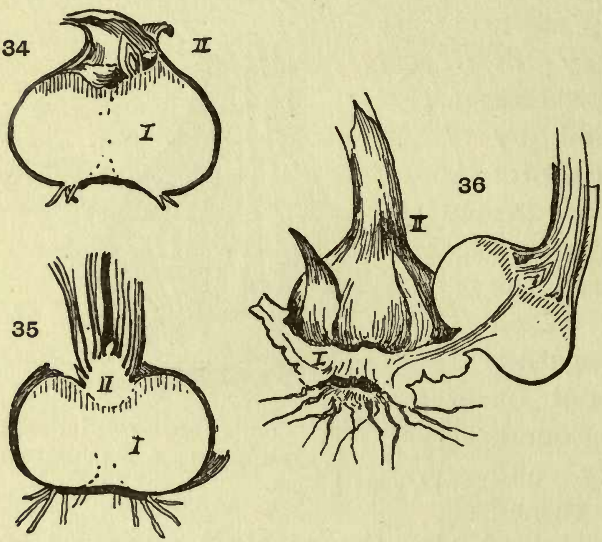
Bulbils are small buds produced in the axils of foliage leaves, as in the Lesser Celandine and some lilies. These bulbils contain stores of reserve material, and dropping off the parent plant form new plants.

(iii.) *By corms.*—The Crocus is an example of a plant which propagates itself by a corm, a structure very closely allied to a bulb and differing from it mainly in the relative porportion of stem and leaves. The greater part of the corm consists of the stem portion, whilst the scale leaves are few; just the reverse is the case in the bulb. It follows that in the Crocus the food is contained in the stem; in the bulb it is stored in the leaves. In order to understand the life-history of the Crocus, corms

should be examined at different times of year, about November, February, March, July. Drawings should be made of each stage and compared with each other.

In November the plant is in its resting condition and shows a large corm bearing a bud in the axil of a scale-leaf, with an old corm underneath it. Roots are given off from the circumference of the corm. (See Fig. 34.)

Early in February a crocus has reached the stage shown in Fig. 35. The corm marked I in Fig. 35 is gradually shrinking, for the bud (II) is feeding on it. If this bud is dissected it will show a succession of sheathing leaves, then a few green leaves, then the floral-leaves all borne by the stem portion of the corm (II). The flowers often come above ground before the leaves ; buds are formed in the axil of one or more leaves at the end of the season, when it is preparing to rest for the winter.



FIGS. 34–36.—Corm of crocus showing three stages of development. The Roman numerals refer to the same corm throughout.

After flowering the crocus appears as in Fig. 36. The corm has very much increased in size owing to the deposition of starch made by the green leaves, which are always tied up by gardeners after the flower has faded. It is seen in Fig. 36 how very much corm I has shrunk ; if undisturbed, it would very soon have been a mere skin under corm II. This figure also shows the development of a corm from a lateral bud, which was present in the crocus from which it was drawn. The development of new corms from lateral buds is an arrangement by which the plant gradually occupies new ground and thus gets more nourishment. This is

very well seen in the Autumn Crocus, a plant belonging to the Lily order and not to the true crocuses. It grows in pastures, and flowers the end of August. It is very like the Purple Crocus. The new corms are formed on one side of, and a little below, the old one. When the corms have reached a certain depth, about 7 or 8 inches, they do not penetrate any deeper, but spread laterally.

The life-history of a Crocus may be summed up—1. It develops from a corm, which is a swollen stem with roots on the lower, and a bud on the upper, surface. In its earliest stage everything is beneath the ground.

2. The flowers and leaves come above ground; the corm shrivels, for it is feeding these organs.

3. Buds are produced in the axil of one or more leaves. The food made by the blades of the leaves is stored up in these buds, which develop into corms, having the structure described in 1.

With the Crocus may be compared the Montbretia. If Montbretia plants are dug up in October, old corms will be found under new ones, as in the Crocus, but in addition to this, long runners or underground stems are also found at the end of the summer. These, swelling up at their ends, form fresh corms at some distance from the mother plant, in order to get food material from a new area. In this way the plant is propagated and spreads rapidly in a garden.

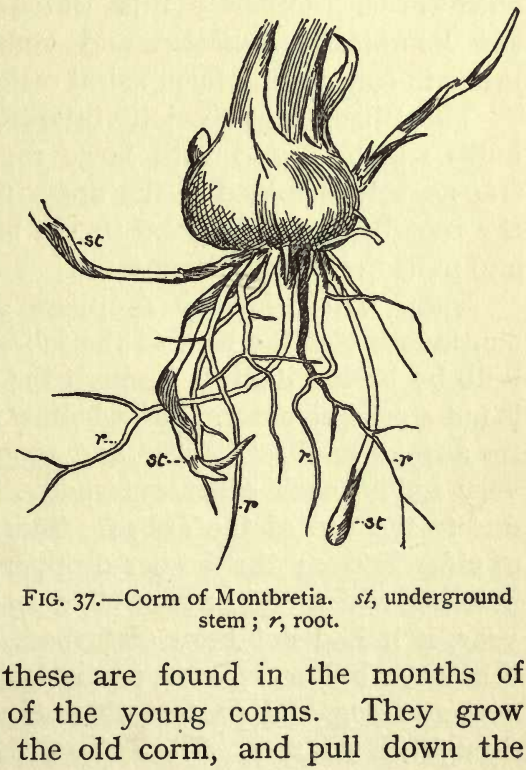


FIG. 37.—Corm of Montbretia. *st*, underground stem; *r*, root.

Both corms and bulbs have the power of forming contractile roots. In crocuses grown in the open these are found in the months of April or May at the base of the young corms. They grow rapidly, sometimes through the old corm, and pull down the

new plant to the soil best suited to it. Kerner mentions a species of Garlic (*Allium paterfamilias*), the old bulb of which gives rise to a hundred young ones in a year. Naturally they could not all develop, if they remained crowded together; by contractile roots the young bulbs are drawn away from the old one. Only a few of the roots, he says, strike downwards; by far the greater number grow out parallel to the soil. With this species may be compared the behaviour of another garlic, *Allium ursinum*, very common in woods and easily recognised by its strong smell. In early spring, it forms a circle of fleshy roots, which grow obliquely downwards. As soon as they are firmly attached to the soil, they contract to about two-thirds of their original length, and thus draw the bulb downwards. In the autumn another set of roots is developed. These grow outwards, and their work is to get nourishment for the plant. Then follows the period of winter rest, and the following spring another circle of contractile roots is developed to drag the bulb downwards. Other plants which have contractile roots are the *Ranunculus bulbosus* and young Raspberry bushes, these latter in contracting form spiral coils.

The Bluebell is specially interesting. In the month of May bulbs will be found with large roots, 4 or 5 inches in length, transversely wrinkled in the upper region. The lower portion of the root being firmly fixed in the soil, the upper part contracts and pulls the bulb underground.

Tulip bulbs develop droppers or sinkers. A dropper is a continuation of the base of the foliage-leaf. It emerges from the bulb by boring its way through the scale leaves enclosing it. It is not a solid structure, but a hollow tube containing in its swollen tip a small knob. Figs. 38 and 39 give drawings of two droppers very unlike each other externally. The difference in length is due to the age of the Tulips. Short droppers are characteristic of older Tulips; the slender dropper probably belongs to a young seedling, and would have swollen up a good deal by the end of the year, if it had not been disturbed. It is by means of droppers that some bulbous plants, particularly Tulips and Squills, prevent overcrowding and protect themselves from frost in winter and drought in summer. The Tulip with the short dropper in Fig. 38,

being much older, has probably reached the level best suited to the plant, whilst the one with the long, slender dropper, being much younger, was still seeking the right depth.

The price that used to be paid for Tulip bulbs strikes us now as incredible. The chief trade in the sixteenth century was carried on by the Netherlands, and it is said that as much as £500 or more would be given for an individual bulb. The bulbs of the Double Hyacinths when first produced at the beginning of the eighteenth century fetched £100. The rivalry that sometimes existed between bulb-growers is well shown by Dumas in his pathetic story *La Tulipe Noire.*

(iv.) *By tubers.*—A tuber (Latin *tumere,* to swell) is a swollen underground stem. A Jerusalem Artichoke should be examined first, as it is then easier to understand the structure of the Potato. The leaves in the Artichoke are long, scaly outgrowths; in the axil of the leaf will be seen a bud. Then the Potato should be examined. It, too, is a much swollen structure, bearing very small scale-leaves with buds in the axils. These are called "eyes" in both the Artichoke and Potato; in the latter there are from two to six buds in each "eye," but they do not usually all develop. As these underground structures in both plants bear leaves and buds, they are underground stems, not roots, for stems alone bear leaves, or structures answering to leaves. As a rule, stems alone may be said to bear buds, although there are one or two instances of a root bearing a bud.

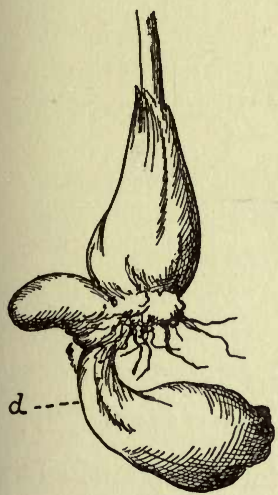


FIG. 38.—Dropper of old Tulip. *d*, dropper.

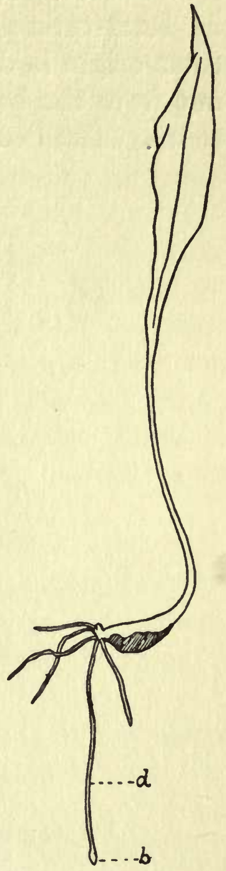


FIG. 39.—Dropper of young Tulip. *d*, dropper; *b*, swelling at tip.

If a Potato plant is carefully dug up without breaking the branches, the relation of the Potatoes to the parent plant can be seen. The tubers are situated either at the end of shoots which bear scale-leaves, or on short branches arising in the axils of the scale-leaves. Both of these are shown in the illustration.

Root-tubers are also swollen, underground structures, but their origin is different from that of the stem-tuber. They grow out from the base of the stem, and are therefore of the nature of roots. The Peony and the Dahlia have root-tubers.

FIG. 40.—Potato plant, showing Potatoes in different stages of growth.

All these tubers are storehouses of food for the plant. If a drop of iodine is put on a slice of a Potato, a dark blue stain is at once produced. This indicates the presence of starch. When good potatoes are properly boiled, they have a floury appearance, owing to the bursting of the grains containing starch.

In preparing " seed " potatoes, a well-grown potato should be cut into as many pieces as there are " eyes " at the apex ; each piece should contain one of the " eyes," and should not be cut too close to it, as the bud when growing into the plant requires to draw nourishment from the tuber. A pound of potatoes will

give about a hundred shoots, reckoning three buds to each "eye." Potatoes do not require as rich soil as many other crops. The best soil for them is a light open soil, well drained, and of a sandy, loamy character. It is interesting to read the directions for planting potatoes which used to be given when they were comparatively new in England. Thus Evelyn in his *Kalendarium Plantarum,* the first gardener's calendar published in Britain, writes, "Plant potatoes in your worst ground." In Mortimer's *Gardener's Kalendar* for 1708 the Potato is thus described: "The root is very near the nature of the Jerusalem Artichoke, although not so good and wholesome but that it may prove good for swine." Gerarde mentions in his *Herbale,* published 1597, that he cultivated the plant in his garden, where it succeeded as well as in its native country. This is one of the earliest references to the Potato in England. That potatoes naturally like a sandy soil was observed by Darwin, who relates seeing the wild Potato growing abundantly among the Chomos Islands near the sea beach in thick beds, on a sandy, shelly soil, wherever the trees are not too close together.

CLASSIFICATION OF SPECIAL FORMS OF STEMS.—1. *Creeping stems.*—These sometimes occur above ground, as in the runners of the Strawberry. Rhizomes are generally underground, as in the Bracken, Iris, etc.

2. *Bulbs.*—These differ from creeping underground stems or rhizomes in having the nourishment contained in the leaves.

3. *Corms,* which have a swollen underground stem and very few scale-leaves.

4. *Tubers,* which bear "eyes" and are swollen parts of underground stems.

The plant thus has more than one way of storing up nourishment. When the plant is propagated by seeds, it is necessary that food for the young seedling should be contained in the seed, or that the seed leaves should be able to make food for it almost as soon as germination begins. If the plant, however, multiplies itself independently of seed, then food must be stored up for it in some other organ, as the root or underground stem. The

character of the food stored up varies with the plant. Perhaps the food most commonly found is starch, which is present in the underground stem of bracken, the tuber of potatoes, and the corm of the Crocus; the leaves of bulbs often contain sugar. Artichoke tubers contain another carbonaceous substance, called inulin, so too do those of the perennial sunflower.

SUGGESTIONS FOR PRACTICAL WORK.—1. Plant bulbs of Onion, or some other plant, in damp sawdust, noting the position of the roots, of the buds, and of the new bulbs. Onion is mentioned as the cheapest bulb procurable.

2. Grow tubers of potatoes in damp soil, some in light and some in darkness. Compare the growth of the two, and make drawings at regular intervals.

3. Plant corms of crocus in sawdust, and make observations at intervals of two or three months. To do this, draw the external appearance of the corm and then cut a median vertical section of it.

4. Look for contractile roots of crocus in March or April, and for droppers in tulips.

5. Compare the underground structures of the Lesser Celandine, the Parsnip, the Pignut, and the Gladiolus. Decide whether they are roots or underground stems. The important fact to bear in mind here is, that stems bear leaves and roots do not.

6. Examine the scales of the Snowdrop, Onion, Tulip, and Hyacinth. See which are entire scale leaves, and which are parts of foliage-leaves, the blades of which have withered.

7. Determine the nature of the food stored up, whether starch or sugar. The former can be tested with iodine, the latter by tasting.

8. Compare the bulb of a Lily with that of a hyacinth, noting the difference in the arrangement of the scales. In the former, the scales simply overlap at their margin, and the bulb is said to be scaly; in the latter the outer leaves completely ensheathe the inner portions of the bulb, which is then described as tunicated.

9. Count the number of plants produced by a single Strawberry plant.

10. Note the rapidity with which certain weeds, if left to themselves, spread. See whether this is due to growth by underground stems or to dispersion of seeds.

11. Note the propagation of plants in gardens by methods such as layering, taking of cuttings, budding, grafting, etc. These are all means of reproduction independently of seed, either from the leaf, or the stem, or a bud—the vegetative organs of the plant, as they are called, for they are the organs engaged in the normal life of the plant, not usually in the special work of reproduction. These modes of propagation have been also developed in plants, which have been introduced from other countries and therefore may not readily form seed in England. Carnations and Strawberries are "layered," that is young shoots are pegged down to the ground, in order that they may become rooted before being severed from the parent stem. Geraniums and many other plants are propagated by cuttings. These are best made in August. A cutting should be made straight under the node, and the sap allowed to ooze out for some twenty-four hours before it is planted in a pot.

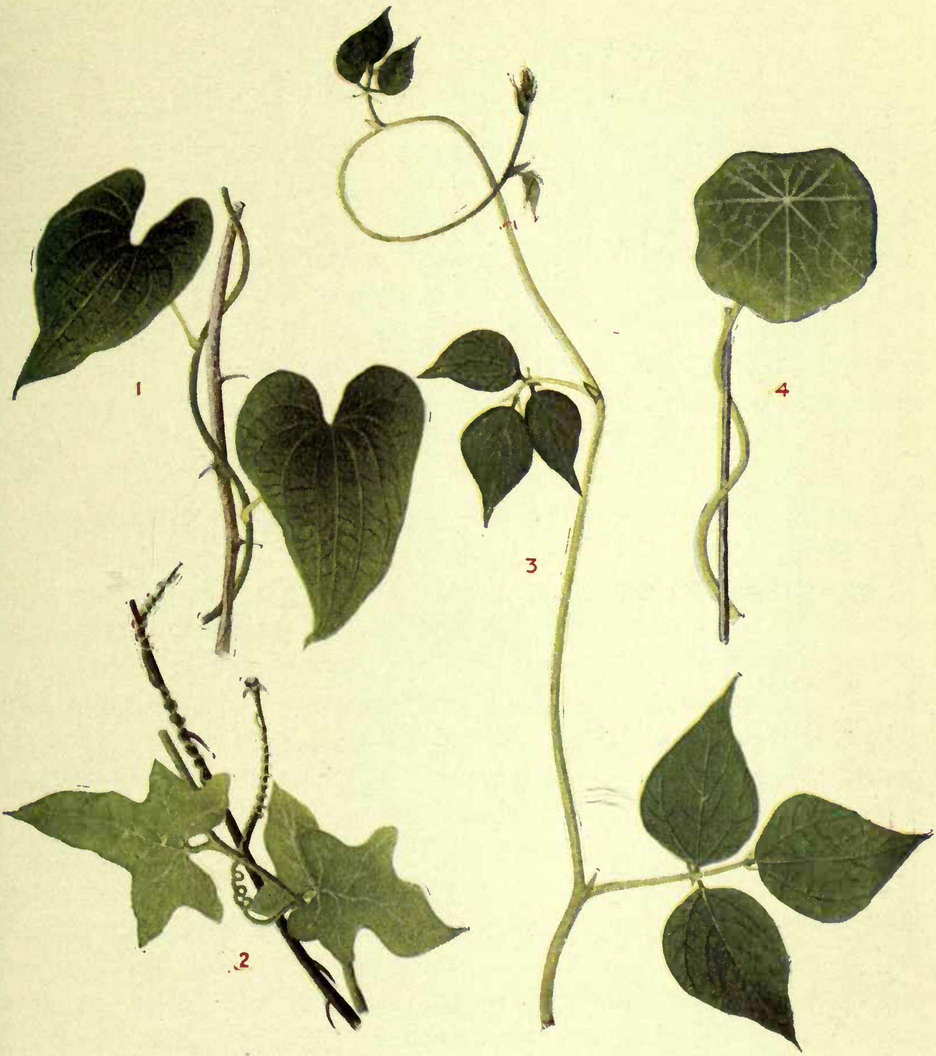
Roses are often propagated by budding. A dormant bud of the variety of rose tree that is to be perpetuated is inserted on a stock which is in the right condition. The Dog Rose is often chosen, and stocks can be obtained from country lanes during the winter. By the following July, the shoot is ready for the insertion of the buds. A plump young bud of the Rose with a little bark attached to it is inserted under the bark of the stock, and the wound bound up, leaving the bud uncovered.

Corms, it may be noted, sometimes form cormlets or "spawn" at their bases. The Gladiolus can reproduce itself in this way. The cormlets are collected and sown in the spring, in beds of rather sandy soil. They are "lifted" from the soil annually, just as older plants are, and flower in about three or four years.

Lastly, it may be mentioned that Begonias are propagated by their leaves. The principal veins are cut through and the leaf pegged down with hairpins, or small stones, on to specially prepared soil placed in a pan or box. The box has to be kept at a certain temperature, and, if properly treated, plants will be

produced at almost every cut of the leaf. Begonias are also propagated by means of cuttings.

Now that school gardens are being established in the majority of elementary schools, opportunity is afforded of first-hand observation of these methods, and the Nature Study lesson may well be planned so as to lead the student to take an intelligent interest in gardening, and to know the reason of these common operations.



CLIMBING PLANTS.

I. Black Bryony, with stem twining from left to right.
II. White Bryony, climbing by means of tendrils.
III. Scarlet Runner, with stem twining from right to left.
IV. Garden Nasturtium, climbing by leaf stalk.

CHAPTER IV

The Importance of Hairs in Plant Life

The term "hair" in its widest sense includes all structures that are developed from the outer skin of any part of the plant; root-hairs, the prickles of the rose, the hairs on stems and leaves, the bristles on many fruits are all "hairs" in the botanical sense of the word. It is evident at a glance that hairs play an important part in plant life, and that their functions are very varied.

Absorption and Digestion.—In germination the root-hairs, as we have seen, are engaged in drinking in food material for the young plant. As soon as the lateral roots are formed the root-hairs behind the tips are engaged in the same work. This has already been fully described (p. 22), therefore we now pass on to the share hairs take in digestion under certain circumstances. There are some plants that feed on insects and obtain their nitrogen from the dead bodies of the insects they capture. These plants are usually found, as one might expect, in soil deficient in nitrogen. The Pitcher-plant, Sundew, Butterwort, and Bladderwort are instances. If these be examined it will be found that the insect is often entrapped by means of hairs on the structures concerned, and in some cases the hairs secrete a fluid which enables the plant to digest the body of the insect. In the Pitcher-plant (Plate II.) the leaf-stalk is modified into three distinct parts: a flattened leaflike lower part; a tendril and a pitcher, the blade of the leaf forming the lid of the pitcher. The insect, attracted by the bright colouring, is caught by the bristles of the rim; unable to escape owing to the fact that the bristles point inwards, the insect falls into the pitcher and is drowned in the liquid which it contains. In the Sundew the leaves are

covered with delicate red hairy-looking filaments, generally called tentacles. Botanically, they are described as "emergences." One hardly ever gets tired of watching these filaments curl up when touched; they serve to entangle the insect. At the extremity of each there is a gland which secretes a juice containing an acid that digests the nitrogenous substances present in the body of the insect. The leaves of butterwort are thickly covered with glandular hairs; it is said that the eight rosette leaves of one plant have as many as 500,000 of such hairs. These aid in the capture of the insect, and the fluid they secrete, in digesting it. The bladders situated on the leaves of Bladderwort are also covered with hairs.

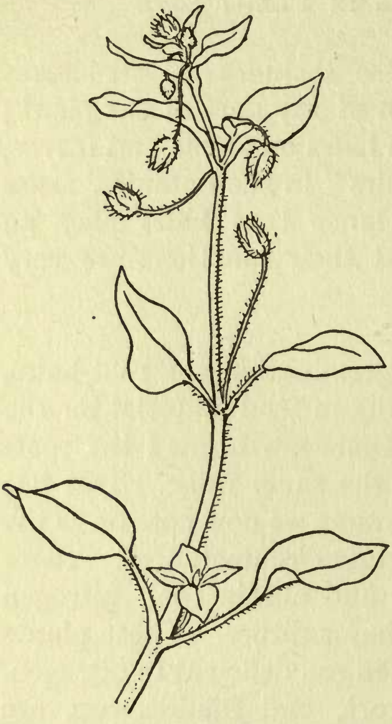


FIG. 41.—Chickweed (*Stellaria media*), showing hairs which drain off water.

IN DRAINING OFF WATER.—The bud-scales of winter buds often bear delicate hairs at their edges. These help to direct the current of water down the bud and thus prevent its reaching the delicate inner leaves, which would rot unless they could be protected from the cold rain of winter. The stipules of the Oak or of the Beech should be examined in spring, when the bud opens and the fringe of hairs will be easily seen.

A very interesting arrangement of hairs occurs on the stems of *Stellaria media* (Common Chickweed). The plant is for the most part smooth, but there is a line of hairs running down the side of the stem which is opposite the flower. The leaves are opposite, and their bases form a cup; the edges of the leaf-stalks are also fringed with long hairs. It is thought that the line of hairs on each internode serves to conduct the water from the cup above to the one beneath. It should be

noted that the line of hairs on the stem alternates with each internode.

PROTECTION.—Hairs are often developed on the stem or leaves, or on both, in order to protect the plant from animals. Stinging Nettles are let severely alone, and some people have supposed that the Dead-nettle has gained some advantage to have leaves which very closely resemble those of the Stinging Nettle. If a Nettle is grasped from below, the hairs which point forwards are merely compressed and do not sting.

These hairs contain an acid fluid, which causes the irritation. The leaves of the common Elm have on their under surface, especially along the ribs, hairs which sting, though not so severely as those of the Nettle. This tree is often planted in hedgerows, and is no doubt protected from browsing animals by these hairs. The teeth of the Holly are a protection to the tree. Lord Avebury notices in this connection that the upper leaves which are out of the reach of animals tend to lose their spines, and old trees are often almost entirely without them. (*British Flowering Plants*, p. 281.)

FIG. 42.—Under surface of leaf of Elm, showing hairs along the ribs.

Another plant which has stiff, almost prickly, leaves protecting it from animals is the Viper's Bugloss.

In some plants prickles are developed instead of hairs. These are often protective in function; they may be also an aid in climbing.

Flowers are sometimes protected from creeping insects by hairs on the involucre, as in *Crepis paludosa*. In the Compositæ it is very common to find the bracts of the involucre with stiff hairs, *e.g.* Knapweed. The stomata of leaves are often protected from dust by hairs. In London parks the hairs on the under surface of the leaves of the Wych Elm are often found covered with soot particles, which are thus prevented entering the stomata.

To lessen Transpiration.—As a general rule plants that grow in dry situations are much more hairy than those belonging to damp places. The different species of a genus illustrate this. *Crepis paludosa* grows in damp places and is smooth, whilst *Crepis biennis* and *Crepis fœtida* are hairy. Professor Henslow, describing the plants of the desert near Cairo, notes the grey colour of the leaves, and attributes it to the dense coating of hairs, which conceal the green colouring matter. The effect of hairs is to lessen the amount of transpiration. This is a most important function, for plants that live in dry situations need to retain as much water as possible, the supply being very irregular. A covering of hairs prevents evaporation from the surface of the leaf into the air. This may be observed on hills, which are always drier than the adjoining valleys and on the seashore. Many of the Hawkweeds and Hawkbits and Crepis have leaves densely covered with hairs, to protect from too rapid transpiration. In the Mouse-ear Hawkweed the under surface of the leaf is covered with stellate hairs; in dry weather the leaf rolls up so that the under surface is uppermost, and evaporation considerably lessened. This decrease of transpiration owing to the protection of hairs is one of the best marked characteristics of alpine plants. The Edelweiss and Cudweeds are instances that will occur to every one.

Fig. 43.—A species of Crepis showing hairiness of leaves.

In this connection it is interesting to note the variation in the degree of hairiness in the same species owing to a difference in situation. The Restharrow (*Ononis arvensis*) is very variable. When growing by the sea it is more hairy than when growing inland. Similarly, it has been stated that Meadow-sweet, which is usually smooth, develops hairs when growing in a dry situation.

Not only do hairs protect against too rapid transpiration, but also against changes of temperature. The young leaves in buds are often wrapped in white downy hairs which protect them from the cold of winter, as in the White Beam tree, which looks in the distance almost white from the thickness of the cottony filaments on the under surface of its leaves.

CLIMBING.—Hairs, especially if hooked, help a plant to climb. Hop-pickers dislike having to pick hops in wet weather, not only because all outdoor work is pleasanter in a bright sunny atmosphere, but on account of the way in which their hands get cut by the hairs, which are much stiffer in damp weather. The leaves of the Hop are covered with hairs, some of which are seen under the microscope to have, as it were, two horned appendages. It is these that enable the hop in its wild state to cling to any support it may touch in the course of growth. Many of the genus *Galium* are provided with hairs for climbing purposes. The best known example is the Wild Cleavers, which is covered with small, stiff, hooked hairs. Not only the stem and leaves are thus provided, but the burrs are even more difficult to get rid of when once they have attached themselves to clothing. Another species of *Galium*, the Crosswort, also has closely packed hairs, though not with such well-developed hooks. Both those plants, especially the Wild Cleavers, are found abundantly in hedgerows. Without some means of climbing they would probably be far less luxuriant in growth, for their stems are weak and the plant would be very likely to be trodden down. Prickles often have the same function. Rose and Blackberry stems catch hold of other plants by means of the prickles developed on them. The Blackberry is often found entwined with clematis. If the two plants are untwisted it will be seen that the Clematis has climbed by twisting its leaf-stalk, the Blackberry by hooking its prickles on to the other plant.

POLLINATION.—Perhaps the most striking use of hairs is their share in the work of pollination. One naturally dwells on the part played by insects in the carrying of pollen from one flower to another, and botanists have always been fascinated by the study of the relation of plants and insects, but hardly enough emphasis

has been laid on the use of hairs. It is owing to the stigmatic surface being covered with hairs that the pollen grains are kept firmly on the stigma, whilst the pollen tube is being put out. In fact, there seems to be a definite relation between the length of the hairs and the size of the pollen grains.

Insects are often entrapped by hairs, in order to ensure cross pollination. The common plant called "Lords and Ladies" (*Arum maculatum*) shows this very well. Small flies are attracted by the dark red spadix on which the flowers are borne, by the smell, and some may fly to the plant for shelter in the large green bract (spathe). They creep down until they reach the upper part of the chamber formed by the bending round of the edges of the bract. Just on a level with the upper part of this chamber the spadix bears hairs which radiate outwards and allow the insects to creep down, but not to get out of the chamber. In reality, they are imprisoned there until they have done the work the plant requires from them. In this plant the stigmas are mature before the anthers. The flies, if they have visited other Lords and Ladies, will pollinate the stigmas with the pollen brought. Then the stigmas wither, and the flies get the honey which is secreted on the tips of the stigmas. Lastly, the anthers mature, the pollen sacs dehisce, the pollen falls to the bottom of the chamber where the flies still are, and they get dusted with it. Then the hairs shrivel up and allow the insects to escape. These, laden with pollen, if they fly to another Arum, will cross-pollinate it. One wonders that any fly, having once tasted of this imprisonment, should repeat the experiment; but it seems certain from the large number of flies found in the chamber of the Arum, that many must visit one flower after another. Lord Avebury states that often more

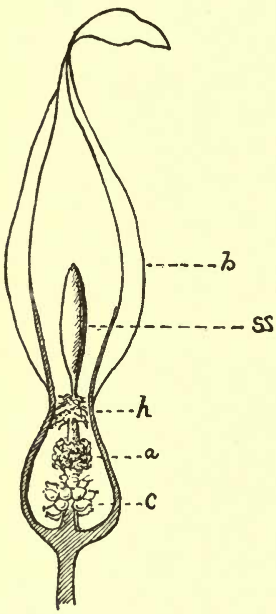


FIG. 44.—Inflorescence of *Arum maculatum*. *b*, bract; *ss*, spadix; *h*, hairs; *a*, anthers; *c*, carpels.

than one hundred small flies will be found, and mentions, on the authority of Knuth, an instance of 4000 being found in a single Arum. It is possible that the honey is exactly the food this species of fly (Psychoda) loves best, or the smell may prove an overpowering attraction. Other very opposite explanations have been given lately. Father Gerard's opinion, quoted by Lord Avebury, is that the honey has a stupefying effect on the insects, which he says are killed and digested in the chamber, for the dried remains of flies are found on the walls of the cavity. It is quite probable, however, if flies visit the flower in such numbers, that some should get killed, owing to the want of oxygen; the presence of a large number alive is a fact largely in favour of the usually received theory.

Hairs may entangle the desired insects, but they may also keep away undesirable guests, thus guarding the nectary and preserving the honey for the insect able to pollinate the plant. In the Dead-nettle the honey is secreted by a nectary just below the ovary, and it collects at the bottom of the corolla. Here there is a ring of hairs which effectually prevent small insects getting the honey, for the Humble-bee is the species best adapted to the structure of the flower.

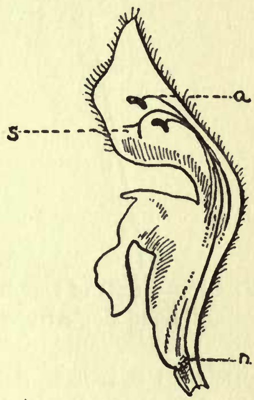


FIG. 45.—Median vertical section of flower of Dead-nettle. *a*, anthers; *s*, stigma; *h*, hairs.

Sometimes flowers have no honey, and insects visit them in order to get pollen with which to feed their young. Under these circumstances some flowers have special staminal hairs to which the insect clings. The mulleins are good examples of this. The Black Mullein, in particular, has on its stamens a row of rich violet-coloured hairs. In all these ways hairs are of use in pollination.

DISPERSION OF FRUITS AND SEEDS.—Many fruits are dispersed by hairs or bristles. It is well known that in many of the Compositæ the sepals are represented by hairs. After the formation of the fruit those develop into organs of dispersion. The

"pappus" of the Dandelion is a case in point. The wind wafts the fruits long distances, and this largely accounts for the wide-spread habit of the plant, and indeed of many Composites, *e.g.* Thistle, Groundsel, Knapweed, Burdock.

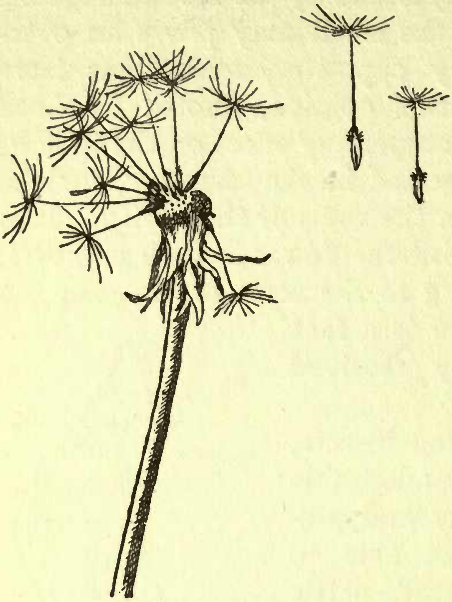


FIG. 46.—Fruits of Dandelion. On the right hand single fruits are shown.

Sometimes the styles become the organ of dispersion through the long hairs developed on them. The Water Avens (*Geum rivale*) has very hairy styles, which no doubt serve to disperse the fruits. Another species of Geum growing at high altitudes, as for instance on Swiss mountains, also has very long hairy almost silky, styles. The most common species in England, *Geum urbanum*, a hedgerow plant, develops styles each of which ends in a hook, and this serves the same purpose of dispersion.

The fruits of the Clematis are too well known to need description, but that of the *Anemone pulsatilla* is much less common, and shows styles even more hairy than the Clematis. In this plant the flower-stalks lengthen after flowering, perhaps also to help in dispersion. In the common Wild Anemone the fruits are downy, but have not got the long feathery awns of the *Anemone pulsatilla*. In this connection the "awns" of the grasses may be mentioned. The most remarkable instance of this is *Stipa pennata*, a species much used in decoration. The Cotton-Grass, really a sedge, has a perianth of long cotton-like hairs which aid in the dispersion of the fruit.

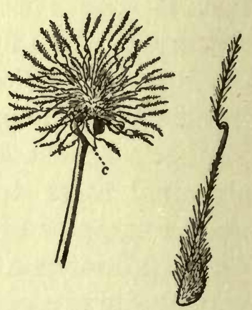
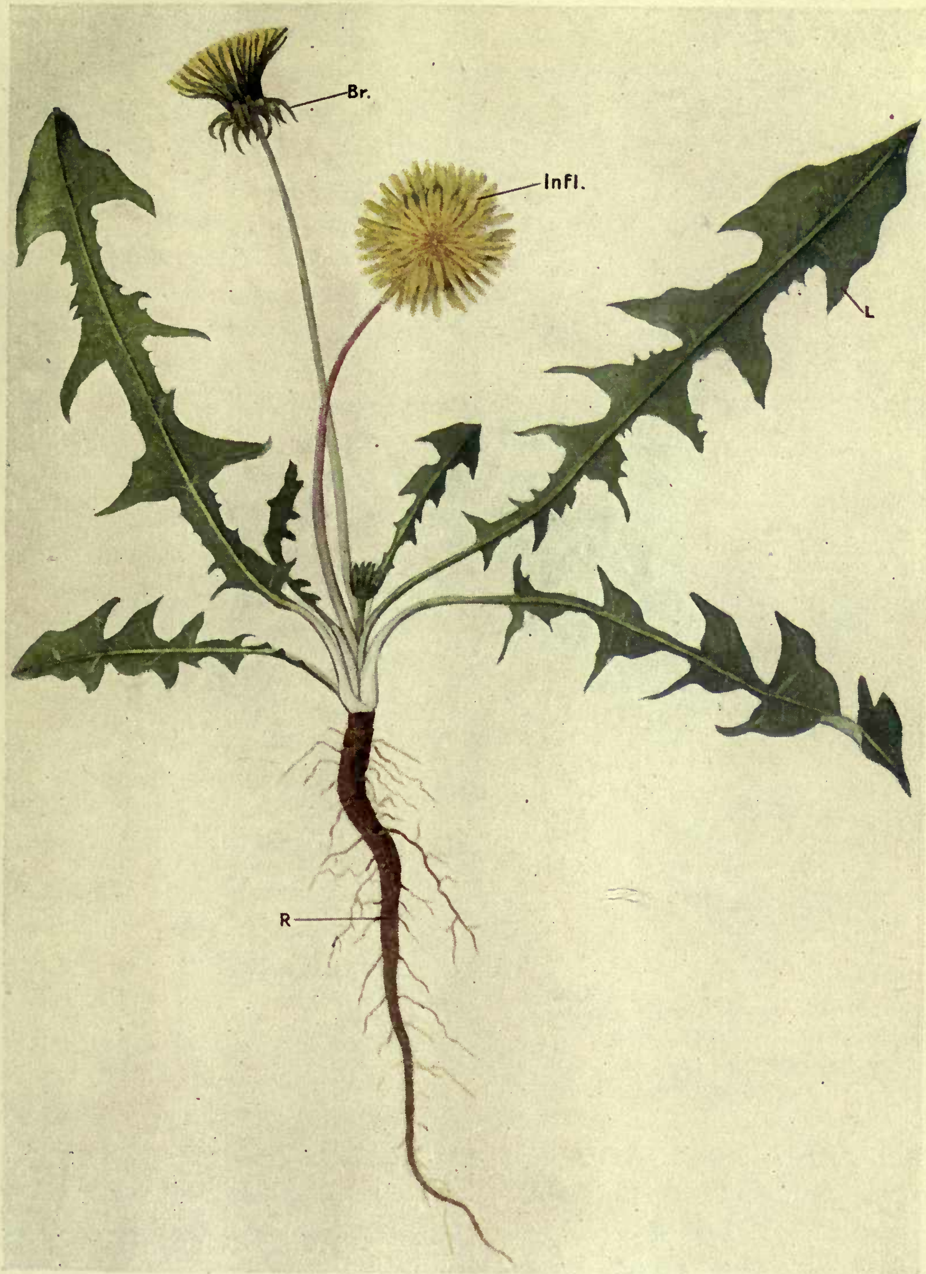


FIG. 47.—Fruit of Water Avens.

In many cases the hairs forming the organ of dispersion are



DANDELION (*Taraxacum officinale*, Web.).

R. Root. L. Leaf. Infl. Inflorescence. Br. Bracts.

attached not to the fruit, but to the seed. The cotton that is imported from Africa and America, and manufactured into calico, consists of the fine hairs in which the seeds are wrapped. One of the factors affecting the price of this raw cotton is the way in which it is picked. It should be absolutely clean, free from every bit of the husk or particle of dirt of any kind.

The Willow-Herbs have seeds wafted by the wind long distances owing to the hairs with which they are provided. So too have the seeds of the Willow, which belongs to a very different group of plants. In the months of May or June the fruits of the willow catkins begin to dehisce. Then the seeds are exposed, and are seen to be covered with delicate silky hairs by which they can be blown long distances. The same thing occurs in the Black Poplar, which is particularly beautiful. The fruits dehisce into two valves, each containing many seeds; the whole catkin seems to be enveloped in snowy white fluff.

FIG. 48.—Fruits of Willow. A single fruit is shown on right, dehiscing and exposing seeds covered with hairs.

STRUCTURE OF HAIRS.—Hairs may consist of a single cell. This is almost invariably the case in root-hairs, which, as a rule, do not branch. Unicellular hairs are generally described as simple. Multicellular hairs, as the name implies, consist of more than one cell; these may be branched or unbranched; they may be filamentous or scaly. Thus the Stock has simple, branched hairs, the Mullein branched compound hairs, whilst the stinging hair of the Nettle is simple and unbranched. This plant has three kinds of hairs; those that sting are the largest. The point of the stinging hair breaks off in the skin, leaving a tiny wound into which the acid juice contained in the swollen base can enter.

The prickles of the Rose are of the nature of hairs, because they are developed from the epidermis. These are often popularly called thorns, but the term "thorn" in botanical language generally represents a modified branch, as in the spines of the Blackthorn and Hawthorn. Sometimes thorns represent modified leaflets, not branches. The leaves of the Barberry plant show an interesting transition from foliage-leaves to spines. The lowest are foliage-like, the uppermost spiny; the intermediate ones are smaller than the lowest, and end in a spiny process, so that they are something between the foliaceous and spiny forms. The thorns or spines of the Gorse are either modified branches or modified leaves: those that arise in the angle which

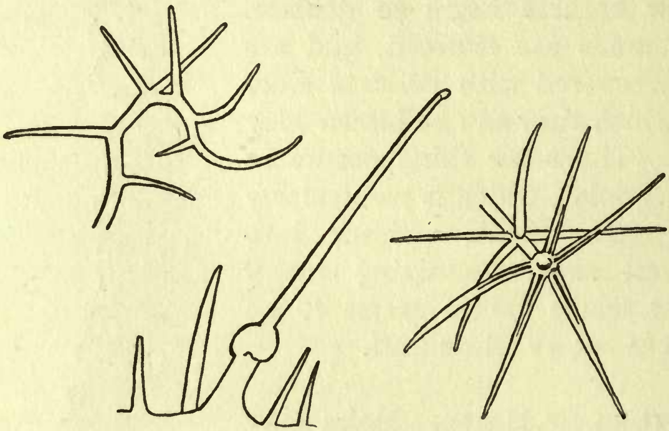


FIG. 49.—Different forms of hairs: Stock, simple, and branched; Stinging Nettle and Mullein.

the leaf makes with the stem are from their position branches; whilst those that are borne laterally by the main stem or branch are modified leaves. The young seedling of the Gorse has trifoliate, ordinary foliage-leaves (Fig. 22), but as the plant grows older these are replaced by spines. It seems likely that these spines have gradually been developed, possibly in the first instance to prevent too rapid transpiration in dry seasons, the Gorse liking a sandy soil; now the thorns also serve to protect the plant from herbivorous animals.

The spines of the Garden Acacia (Robinia) may also be mentioned. These arise at the base of the leaf-stalk, and are modified stipules.

It is interesting to compare the structure of the same plant growing in different situations. The Rest-Harrow is more thorny in dry situations than in moist valleys, the Meadow-Sweet appears to have almost entirely smooth leaves, when growing in damp places, and to develop hairs on the leaves in drier soil.

Much more accurate observation needs to be made on this subject of the hairiness of plants. Although it may be stated generally that plants belonging to dry situations are hairy, there are many exceptions of which as yet no explanation is forthcoming. Why are those Forget-me-nots which grow in damp places hairy ? The reason may possibly be that they belong to an order of plants which is conspicuously hairy. The Viper's Bugloss, Borage, Alkanet are all strikingly so. Then the Water Forget-me-nots and Comfrey, which also belong to damp situations, and might be expected to be smooth, are also hairy. As a rule, structures of this kind are not necessarily affected by facts of relationship. There are numerous instances of very closely allied species, which differ in this character of hairiness according to the situation in which they live. Another explanation that is sometimes suggested is, that these hairy plants now found in wet ground, as by streams, etc., at one time grew in drier situations, and that they have not yet lost the hairy character which then was of use to them. It is impossible in the present state of our knowledge to account for these differences. More accurate observation of the same species under different conditions is necessary, and one or two suggestions are now offered.

Examine the leaves of plants growing by streams, or in marshy places, such as the Meadow-Sweet, Ragged Robin, Cuckoo Flower, Water Avens, Figwort, etc., and note whether they are hairy or not. Compare them with other plants of the same species growing in drier situations, as for instance in land which was marshy but has been drained.

Compare plants of the same species growing on hills and by the seashore ; the common Erodium will be found in both these habitats. Note the degree of hairiness. As a rule, plants growing in both these localities are hairy, on account of the dryness of the situation. Not only are plants by the seashore inclined to be hairy, but they often have their leaves reduced to spines.

The Saltwort is a typical instance of this. The Salt Spurrey, though it has fleshy leaves, develops scaly stipules ; the apparent leaves of the Glasswort are branches, which are jointed, and the true leaves are represented by the small teeth at these joints. In fact, there is no organ of the plant which adapts itself to its environment more readily than the leaf ; by becoming hairy, or thorny, or very much reduced.

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SOME COMMON FLOWERING PLANTS.

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CHAPTER V

Introductory

For the student of nature knowledge, and especially for the teacher, the study of the flowering plants of our fields and gardens is of especial importance. They are of great interest, but so are all other living beings and natural objects. It is their familiarity and the ease with which they can be obtained that gives them a place before many other things in Nature Study, and the teacher is sure to draw largely upon them in his efforts to interest his scholars. One great advantage is that they can not only be easily obtained, but obtained *in quantity*, and no lesson need, or ever should, be given from a single specimen. The scholars may sometimes be able to collect the plants required for themselves, and, if common kinds are chosen, each child can have his own specimen to study. Another advantage is that the flowering plants are easily grown and watched through the various stages of their life, and at the different seasons of the year.

Every flowering plant has its own interest and, in the hands of a teacher who has himself studied it properly, will serve as the basis for interesting lessons. The commonest and most familiar plants are, however, in many ways the best to use. Familiar wild flowers of the meadows and roadsides, common trees and plants grown in gardens, as vegetables, fruit trees, or for the sake of their flowers, afford excellent objects of study. That the common

plants are the most suitable to begin with is the principle underlying this section of the Nature Study Book.

The study of flowering plants may be begun in several ways, and the difficulties for the unassisted student lie in great part in making a proper start. One very common method is to start by trying to name all the plants met with in a district by the help of a book of descriptions, or what is known as a Flora. This is an excellent thing to do later on, but has disadvantages as a way of beginning. The student is liable to be bewildered by the number of plants, and the descriptions are necessarily brief and concerned with the features that serve to distinguish one plant from another rather than with their uses to the living plant. An opposite course, the thorough study of the life history, form, and minute structure of one plant, requires the assistance of a teacher and more complicated apparatus than the plan which is here suggested.

We shall start from the fact that, however slight his real knowledge of plants may be, every one knows a number of wild and cultivated plants by name, and can recognise them when in flower. The Buttercup, the Daisy, the Dandelion, the Tulip, the Potato, and the Oak, for example, may be assumed to be either known to the reader, or at least to be so commonly known that he will have no difficulty in getting them pointed out to him, and in obtaining specimens for study. In the following pages a number of plants, which may thus be assumed to be familiar, have been selected, and a description given of what can be seen when they are carefully examined with the assistance of only simple apparatus. This description is meant to help the teacher in his own study of the plant. His teaching should be based upon his own observations, not upon this or any other written description.

It was mentioned as one of the drawbacks of commencing by naming the plants of a district, that it concentrated attention on the differences between plants without considering the relation of these differences to the life of the plants. In studying the plants described below, the use to the plant of the various parts is always to be borne in mind. It will be found that the general features in which flowering plants resemble one another are related to processes of life common to all these plants. Special features of the roots, stems, leaves, and especially of the flowers, require

careful study in the light of the particular uses these parts serve, and the way in which these uses are carried out. The study of even a small number of plants from this point of view will enable the student to examine with interest and profit other plants than those described here. It will also suggest further work in various directions, some of which are treated of in other sections of this book.

It cannot be too strongly impressed upon any one commencing the study of plants that reading about plants is by itself of little use, and may even be worse than useless if it leads to the neglect of observation. What should be aimed at by teachers as well as scholars is first-hand information based upon the student's own observation. He should know a thing, not because he has been told it, but because he has seen it for himself and understood it. This is a truism, but one of the most difficult things to cultivate is the frame of mind which is not content until the knowledge acquired is based on personal observation and not on hearsay. It is most important that right methods of work should be followed from the outset, and it should be expressly stated that the descriptions below are intended to be used along with specimens of the plants to assist in their detailed study. The order in which the plants are examined is of little or no importance. Plants which are known to be in flower at the particular season should be selected. Evidently the spring and summer months will be the most suitable season for this branch of Nature Study, though observations on the plants should be continued throughout the year. Advice as to collecting and examining plants and as to the apparatus needed will be given below.

All the plants to be described here are what is known as Flowering Plants, and all except the Pine belong to the great group of the Angiosperms. This is the highest group of the vegetable kingdom, and includes the plants which appeared last on the surface of the earth, where they now form the dominant and most conspicuous part of the vegetation. The Pine, which will also be described, belongs to a more ancient group, the Gymnosperms, and will be found to differ more profoundly from the others than they do among themselves. All the plants we are concerned with are composed of similar parts, and have much in

common, but each has its own peculiarities and differs not merely in appearance but in mode of life from the others. The common features are so many, however, that a certain amount of repetition is unavoidable in descriptions which are to be used independently of one another.

To avoid this as far as possible it seems advisable to give at the outset some general ideas as to the parts of which all flowering plants consist, and of their uses. The student must refer to ordinary botanical text-books for further details, for only the main facts necessary for our special purpose will be briefly stated here. In doing this it will be convenient to introduce some necessary names or terms, which will be used in describing most of the plants.

A word may be said as to the use and abuse of technical terms in the study of plants. Far more terms are employed in the concise describing and cataloguing of the many different kinds of plants than are of any use in studies such as this. To avoid the use of technical terms altogether would not, however, be an advantage. In studying plants, and the parts of which they consist, we are in much the same position as when we consider any class of machines and their way of working. It is obviously inconvenient, for instance, to speak about bicycles and avoid technical terms. In addition to such terms as saddle or wheel, which exist in everyday language and only find special application, handle-bar, hub, and tyre are all technical terms which are found useful. There is no more justification for taking unnatural trouble to avoid the use of a convenient term in botany than for talking of "the cross piece by the ends of which the rider holds on," instead of calling it the handle-bar. A certain number of technical names for parts of the plant that we have to distinguish repeatedly will be found of use, and be freely employed in the descriptions. These will be found to present no real difficulty, but it is of course quite justifiable to still further reduce the number of such terms, or even to avoid them altogether in teaching children.

In looking at the parts of which an ordinary flowering plant consists, and the chief modifications they present, it is useful to have a particular example to refer to. For this purpose we shall

take the Buttercup, not for straightforward description, as in the succeeding examples, but as a text from which "digressions" can be made, to consider a number of necessary preliminaries.

The selection of the Buttercup at once leads to the consideration of the *naming of plants*. Each kind of plant requires to be given a distinct name, by which it can be referred to without risk of confusion with other kinds. Since only the more prominent and distinct kinds of plants have been noticed and given local or English names, difficulties arise in the use of these. Whenever possible it is well to refer to common plants by their English names, and these only should be used in teaching children. The English name, however, often applies to two or three plants, and even when it is clearly applied to one kind only, different names may be given to this plant in different localities. In other countries different popular names will apply to the same plant. For these and other reasons it has been found of the greatest use to give a definite scientific name to each kind of plant. This name is the same in all countries, and a knowledge of it, even when for ordinary use the English name is sufficient, makes it easy to consult books giving information about the plant. Since the time of Linnæus, who laid the foundation of the modern methods of naming and describing plants and animals, the scientific name has consisted of two Latin words. Thus three kinds of yellow-flowered Buttercups are found commonly in our fields and hedgerows, and these, together with some rarer kinds, are all usually called Buttercup. Distinctive English names are hardly in common use since the ordinary observer does not distinguish between these plants. The three kinds are the Upright Buttercup

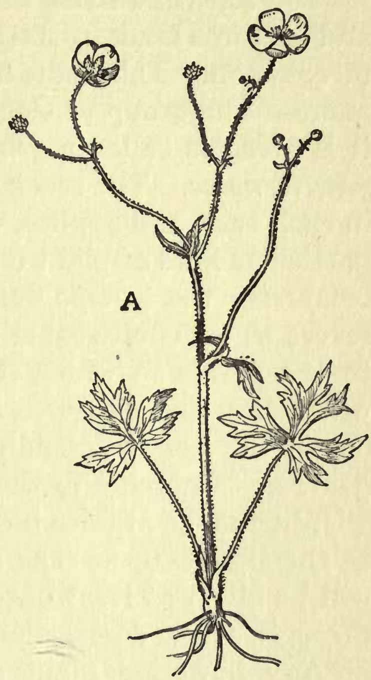


FIG. 50.—Plant of Upright Buttercup (*Ranunculus acris*). (After Farmer.)

(*Ranunculus acris*, L., Fig. 50), the Creeping Buttercup (*Ranunculus repens*, L., see Plate), and the Bulbous Buttercup (*Ranunculus bulbosus*, L.). Without entering into other details, it may be said that the two latter kinds may be distinguished from *Ranunculus acris* by having creeping branches by which the plant spreads in *Ranunculus repens*, and by having a globular, swollen base to the stem in *Ranunculus bulbosus*.

The scientific name in each case consists of two Latin words, and all three kinds of Buttercup have the first name, *Ranunculus*, in common. This may be compared to a family name or surname. The group of closely related and similar plants to which it is given is called a *genus*, and this name is spoken of as the *generic name*. The second name, on the other hand, is different in each case, and applies, when joined to the generic name, to one particular kind of plant only; it is the name of the kind of plant or *species*, the *specific name*. Thus the scientific name not only serves as a definite label for the kind of plant, but gives a clue to the plants to which it is most nearly related. An example will make this clearer. Among the descriptions will be found one of the Lesser Celandine (*Ranunculus Ficaria*). The English name gives no clue to the real relationship of the plant, but the scientific name at once indicates that it belongs to the same genus as the Buttercups. The scientific name of each plant described will be given at least once, even when the English name is used throughout the description.

Any flowering plant appears, even on the most superficial observation, to be composed of a number of distinct parts. So obvious is this that ordinary language has names, which on the whole are correctly applied, for all the principal parts. We distinguish in any entire plant such as the Buttercup, when dug up carefully, the *roots*, the *shoots* composed of *stems* bearing *leaves*, and the *flowers*. It is characteristic of all living beings, both animals and plants, that their bodies are differentiated into distinct parts, each with its own duties to perform in the life of the whole. These parts are called *organs*, and living beings are on this account often spoken of as organisms. Just as the eye, the ear, or the hand have their special duties or *functions* to perform in seeing, hearing, and grasping, and are suitably formed

to exercise these functions, the construction of the various organs of the flowering plant can only be understood in the light of a knowledge of their main functions.

The whole *root-system* of many flowering plants is developed from the main-root of the seedling. This grows down into the soil, and gives off branches similar to itself. These branches arise at some depth in the main root, and burst through the surface layers of this. They grow obliquely downwards on all sides, and in turn bear finer branch roots. The mass of soil around the base of the plant is thus thoroughly penetrated by the roots of the latter. In the Buttercup no main root can be distinguished. The plant is fixed in the ground by numerous, rather stout, whitish roots springing from the base of the stem. These bear the finer branches. The characteristic features of most roots can be well studied in the root system of a Bean seedling. They need only be briefly mentioned here. The cylindrical shape, the absence of the green colour found in the parts of the plant exposed to the light, and the deep origin of the branches are common to nearly all roots. All the branches are essentially similar, and the root never bears leaves. The roots have to make their way between the particles of soil, and the growing tip of every branch is protected by a little sheath of firmer tissue called the *root-cap*. The root enters into very close contact with the mineral particles making up the soil, by means of delicate hairs, which grow out in large numbers from the surface. These are called *root-hairs*, and are found a short distance behind the tip of the root, dying off on the older parts behind.

All these features are related to the uses or functions of the root. In the first place, the root-system serves to fix the plant firmly in the soil. The growth of the roots in all directions through the soil round the base of the plant, and the close connection between the roots and the particles of soil, fit it admirably for this. The same relations between the root and the soil also enable the root to obtain from the soil a part of the food which the plant requires. A plant takes up no solid food ; all the food materials which it absorbs are taken up in a state of solution or in the gaseous form. By means of the root, water, in which are dissolved small quantities of certain substances of relatively

simple chemical composition, is obtained. The close connection between the root-hairs and the particles of soil enables the plant to withdraw water from soils that appear almost dry. The water with its dissolved salts is passed up into the stem and reaches the leaves.

The *shoot* differs greatly in appearance from the root. It is composed of two distinct parts, the stem bearing the leaves. The leaves are usually flat and green and of limited growth, and thus differ from the stem, which bears them, both in form and in construction. At the tip of the shoot we find the young leaves closely crowded and folded over the summit of the stem. The actual growing point of the shoot and the youngest developing leaves are thus protected by the older leaves. The whole structure is known as a *bud*. As the bud unfolds, the regions of stem between the attachments of the leaves lengthen as a rule more or less. The fully grown shoot has thus the leaves attached at certain parts, called *nodes*, which are separated by intervening regions known as *internodes*. The shoot branches, that is new lateral shoots like the main shoot, are developed on the latter. In their young condition these are found as lateral buds occupying a constant position with regard to the leaves. Usually a single bud is developed in the angle between each leaf and the stem. This angle is known as the *axil* of the leaf. Many of these buds may remain of small size, but some grow on into branches.

The *stems* of plants are usually more or less cylindrical. The *leaves* are characteristically thin and flat, with a clear distinction between the upper and lower surface. A number of parts can usually be distinguished in the leaf. The thin flat portion, or *leaf-blade*, is the most important, and may form the whole of the leaf. Usually the region by which the leaf joins the stem is more or less widened out. This is the *leaf-base*, which may form a definite sheath encircling the stem. Between the leaf base and leaf-blade there is often a narrower stalk-like region bearing the leaf-blade at a distance from the stem. This is the *leaf-stalk*. In many but not all leaves there are two outgrowths, one on either side of the leaf-base, known as the *stipules*. In examining a leaf it is well to bear in mind the possibility of its being differentiated into leaf-base with stipules, leaf-stalk, and

leaf-blade. The leaf-blade may be unbranched, although its margin is more or less deeply indented, and is then described as *simple*. In other cases the leaf-blade is branched, and appears to be made up of a number of smaller leaf-blades or leaflets. Such leaves are described as *compound*. The leaflets are most commonly arranged on either side of a stalk which continues the leaf-stalk (*pinnate leaves*), but they may diverge from the end of the leaf-stalk like the fingers of a hand (*palmate leaves*).

The blade of the leaf or of the separate leaflets is traversed by a branched system of conducting and supporting strands which form the *veins* of the leaf, and persist as leaf skeletons when the softer parts have rotted away. There is often a central vein or *midrib* running from the base of the blade to its tip and giving off lateral branches, while the fine network extends in the intervals between these. In other cases no midrib is distinguishable, but numerous parallel veins run in the leaf, connected at intervals by finer veins, and so forming a network in a different way. The stronger veins often project on the lower surface of the leaf, and the whole system serves to support the thin expanded blade. The veins are the ultimate branchings of a system of conducting strands which run continuously from the root to the stem and out into the leaves. It is by means of them that the water taken up by the root is brought to the leaf-blade.

In the special case of the Buttercup the base of the stem is relatively stout, and bears a number of long-stalked leaves which are closely crowded together at their insertion and thus appear to spring from the level of the ground. Above this the internodes of the stem lengthen, but only small leaves are borne at the nodes. The branches in the axils of these bear the flowers. In the axils of some of the lower leaves, in the case of *Ranunculus repens*, long creeping branches arise, to the consideration of which we shall return. The stem is cylindrical, green or reddish, and hairy. Each foliage-leaf has a wide sheathing base, but no stipules. The leaf-base becomes more strongly concave on passing towards the leaf-stalk, on reaching which the thin expanded margin stops. The long firm leaf-stalk is green, and sparsely covered with hairs. It is strongly convex below, but has a narrow, shallow groove on the upper side, *i.e.* the side

facing the stem. The leaf blade consists of three lobes, two attached opposite to one another by very short stalks, and the third borne on a continuation of the leaf-stalk. Each leaflet has a triangular outline widening out from the base, and is in turn divided by deep indentations into three lobes, the margins of which are toothed. The lower surface and margins of the blade bear long and fairly stiff, white hairs. The branching of the shoot proceeds from buds in the axils of the leaves, but as it is seen only in the region bearing the flowers, or in the production of creeping branches, its consideration may be deferred.

The almost universal differentiation of the shoot in the higher plants into a stem bearing thin flat leaves points to these parts performing important functions different from those of the root system. The leaves especially are constructed to play an important part in obtaining and preparing the food materials, at the expense of which the plant grows. We have seen that the roots absorb water, in which salts are dissolved, from the soil. This passes up the stem, which thus serves to support and display the leaves, and as the path by which the water reaches them. The water passes up the leaf-stalk and is distributed by the veins through the leaf-blade. The ordinary leaf-blade is characteristically thin, and exposes a large surface to the air. One use of this is to enable the plant to get rid of a great part of the water absorbed by the roots ; this water escapes in the form of vapour. The salts dissolved in it are left behind and accumulate in the leaf, where they form part of the food material needed by the plant.

The expanded shape of the leaf, together with the green colour found in most parts of the plant exposed to the light, but especially in the leaf-blade, fits the leaves for their other great use in the life of the plant. The plant takes up, mainly by its leaves, a gas called carbonic acid gas, which exists in small quantity in the air. From this gas, and not from the soil, the carbon, which is one of the most important food materials of the plant, is obtained. From the carbonic acid gas, the water and the salts, which we have now followed to the leaf-blade, a green plant can build up more complex substances and continue to live and grow. The process of construction of these complex

materials requires the assistance of energy, and this is derived from the rays of the sun. The leaf displays its broad flat surface to the sunlight, the blade being usually expanded at right angles to the rays of light. The green colour serves to catch certain rays of light that are required in this important process of food manufacture. The characteristic green colour of vegetation thus indicates a widespread similarity in the mode of feeding of plants.

Even this very brief outline of the uses of the root, stem, and leaf will show how they co-operate in the nutrition of the individual plant. The manufactured materials may either be at once used for the growth of the plant (at their expense new roots and shoots are developed), or they are carried away from the leaf and stored up for the subsequent use of the plant or its progeny. Many individual plants live and grow for years without bearing flowers or giving rise to new individuals. They require for this only the organs which have been described, the roots, stems, and leaves, and these are often spoken of on account of this relation to the growth of the individual as the *vegetative organs*, and contrasted with the *reproductive organs* by means of which new individuals are produced. The similarity in general features of the roots and shoots throughout the Flowering Plants shows that the mode of nutrition is similar. When we meet with modifications affecting the whole plant or particular organs, we have to study them in the light of the altered functions of the organs, or of the more profound change in the nutrition of the plant.

However long the life of a plant may be, it is limited. Some Flowering Plants live for many years (perennial plants), others live for two seasons and die after they have flowered in the second year (biennial plants), while others are annual plants only, living for a single season. Like all other living beings, flowering plants have therefore to provide for the formation and establishment of new individuals, *i.e.* for *reproduction*. This is always effected by the separation from the parent plant of a larger or smaller part, which is capable of continuing to grow and of becoming an individual like the parent. Sometimes the part which is separated is a bud or a more or less modified shoot,

and when the multiplication in number of individuals is thus carried on by the vegetative organs we speak of *vegetative* or *asexual reproduction.* The special organ of reproduction of the flowering plants is, however, the *flower,* from which, as a result of complicated processes, into which we shall not enter in detail, the *seeds* are formed and separated as the reproductive bodies from which new plants arise. Since two minute parts or cells of the plant have to unite to give rise to the new individual in the seed, the reproduction effected by the flower is distinguished as *sexual reproduction.* Both vegetative and sexual reproduction are found in the Creeping Buttercup (*Ranunculus repens*).

This plant spreads vegetatively by means of the creeping branches already mentioned as arising in the axils of some of the lower leaves. These branches, which are called *runners,* have elongated internodes, and do not stand erect but lie along the surface of the soil. At each node is a single foliage-leaf, in the axil of which is a bud. This bud grows rapidly, and sends down a number of roots into the soil; it thus comes to possess all the vegetative organs of a complete plant. At first the new plants that are established in this way all around the parent are connected to the latter by the runners, but in time the internodes of these decay and the new plants become independent. It is most instructive to select a strong plant of the Creeping Buttercup growing in open ground, and to trace the spread of new plants around it. Many of the runners are a yard or more in length, and may give rise to a number of plants. Probably most of the plants of this kind of Buttercup that are met with have arisen vegetatively. It is much more difficult to be sure that a plant of *Ranunculus repens* has come from a seed than it is in the case of either of the other two common species which have no runners. In considering the success and the means of

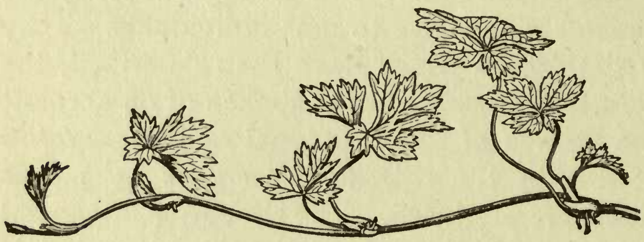


FIG. 51.—Runner of Creeping Buttercup. (After Baillon.)

THE CREEPING BUTTERCUP (*Ranunculus repens, L.*).

spreading of a plant, any arrangements to ensure its vegetative reproduction should always be looked into carefully.

The *flower* of the Buttercup is a very suitable one to examine in the first place, and in the light of its study we shall be able to consider some general features of flowers which will prepare the way for the special descriptions of plants which follow. We have seen that the flower is the part of the Flowering Plant by which the seeds are formed, as a result of a complicated process of sexual reproduction. The flower can thus be recognised as the organ of sexual reproduction of the Flowering Plant. In its construction the flower is a shoot specially modified for this purpose. It consists, as we shall see, of a stem bearing lateral organs, which correspond to leaves, though very unlike the foliage leaves in appearance. Further, the flowers are always borne on the shoot, never on the root, and in their position correspond to branches. As a rule each flower will be found to stand in the axil of a leaf, which is often much smaller than the foliage-leaves of the plant, and is called a *bract*. The flowers are often grouped together on special regions of the shoot, the whole association of flowers forming what is known as an *inflorescence*.

In a strong plant of the Buttercup the main shoots, after bearing the crowded foliage-leaves described above, lengthen and become branched. If carefully looked at it will be found that the main shoot ends in a flower, and similarly the summit of each branch bears a flower. This whole region of the shoot may be called the inflorescence, and, in contrast to the vegetative region below, it has elongated internodes, while the leaves borne singly at its nodes are reduced in size and differ in form from the foliage-leaves. The uppermost of these reduced leaves (bracts) may consist only of a sheath and a small green blade. Branching takes place from the buds in the axils of the bracts. The flower at the end of the main shoot is the first to open, and is followed by those terminating the branches. From the axils of the small bracts on the latter further branching proceeds. The whole of this region of the shoot, with its reduced leaves and numerous flowers, has evidently the display of the flowers rather than of the leaves as its function (Fig. 50).

Many other inflorescences are constructed on the same general

plan as that of the Buttercup, the essential feature of the branching being that the main shoot ends in a flower, and that further flowers are borne terminally on lateral branches. Such inflorescences are called *cymose*. In contrast to such an arrangement of the flowers we shall meet with many inflorescences in which the main shoot does not end in a flower, but continues its growth while the flowers are produced in regular succession as lateral branches. These are called *racemose*. The two modes of branching will be evident from the diagram (Fig. 52), and a

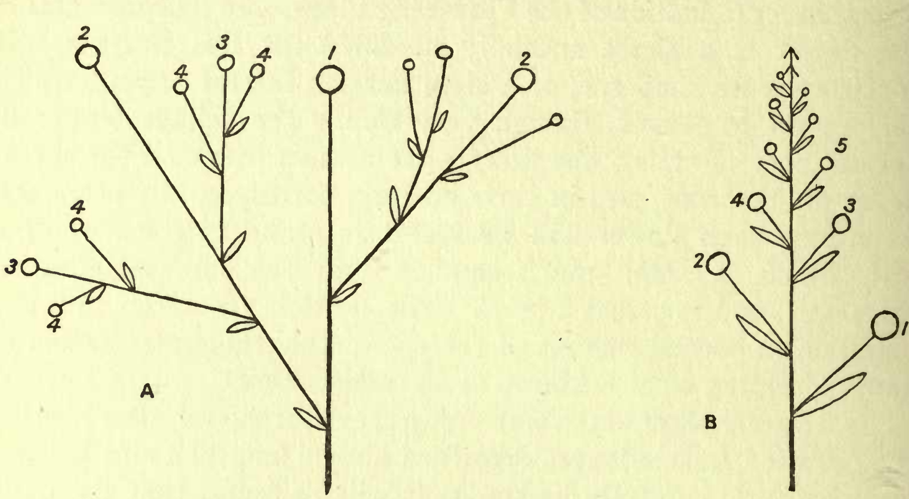


FIG. 52.—Diagrams of (A) cymose inflorescence, and (B) racemose inflorescence. The numbers indicate the order in which the flowers open.

recognition of the distinction between them will be of use in dealing with special examples.

The flower of the Buttercup is borne on a slender, green *flower-stalk*. This in *R. repens* is marked by slight longitudinal grooves, and, like the stem, bears whitish hairs. At the upper end of the flower-stalk a number of floral leaves of different kinds and very different appearance are crowded together, forming the flower. These parts are of four kinds. On the outside are five green leaves, within which come five larger and more conspicuous yellow leaves. Still further in are a large number of narrow stalked yellow structures, and in the centre are a number of small green bodies closely crowded together. The relative positions of these parts will be best understood if a flower is cut in half with

a sharp knife and examined through a lens (Fig. 53, B). It will then be clear that all these parts are borne laterally on the flower-stalk, *i.e.* that they stand in the same relation to this as leaves to the stem. The slightly widened, conical end of the flower-stalk to which the floral leaves are attached is known as the *receptacle* of the flower. As contrasted with the ordinary vegetative shoot, growth usually stops with the production of the floral leaves, and the latter are not separated by internodes.

The outermost series of floral leaves consists of five narrow green structures, the inner face of which is concave and smooth, while the outer surface is clothed with long whitish hairs. These parts are more obviously leaf-like than the other parts of the flower. They are called the *sepals*, and together form the region of the flower known as the *calyx*. When the flower is young, in the condition of a bud, the sepals are closely overlapped, and completely enclose and protect the more delicate parts within. Those edges of the sepals which were thus covered over can be distinguished by their thinner texture and yellow colour. When, as is the case with the sepals of the Buttercup, a number of leaves are borne at the same level on the stem they are said to form a *whorl*.

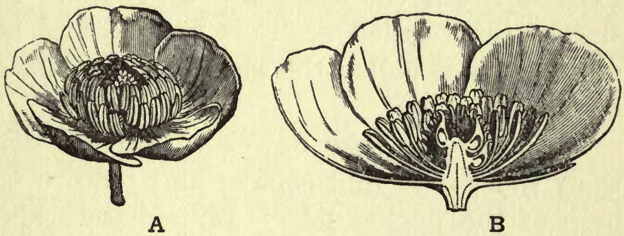


FIG. 53.—Flower of Buttercup. A, whole flower; B, flower cut in half. (After Baillon.)

The five conspicuous yellow leaves, which come next within the calyx, are called *petals*, and together make up what is known as the *corolla*. The petals also form a whorl, and stand higher on the floral receptacle than the calyx. As is usually the case, where the number of parts in the succeeding whorls is the same, the five petals do not stand immediately above the five sepals, but above the intervals separating the latter. The petals are said to *alternate* in position with the sepals. The petals are the parts which give the flower its prominent and attractive appearance. Though flat and leaf-like in shape, they are very unlike

the foliage-leaves or the sepals in texture and colour. Each is attached by a narrow base to the receptacle, and widens out gradually from this to the rounded margin. Except for a region of the upper surface close to the attachment where the colour is paler, the petal has a bright yellow colour ; the surface is dull below, but smooth and shining above. Everything about the petals shows that they are of use in making the flower conspicuous. The reason for this we shall see later.

If a petal be carefully pulled off and looked at from the inner or upper side another feature of interest will be noticed. Close to the base of the petal is a small yellow scale ; this is short, and is almost as broad as the narrow part of the petal against which it lies. The free edge of the scale can easily be raised with the point of a knife, and a little recess or pocket will be found to exist between the scale and the petal. In this pocket a sweet sugary juice called *nectar* is formed and held, and the structure secreting it is called the *nectary*. The use of the nectar will also be seen shortly.

The parts of the flower within the corolla are less leaf-like than the petals and sepals, and require careful study with the help of the pocket lens. Immediately above the petals on the receptacle come a large number of *stamens*. They do not form whorls, but are spirally arranged. Each stamen is composed of a cylindrical stalk, bearing a widened, flattened portion ; the stalk is called the *filament*, the upper part the *anther*. The whole stamen has a more or less intense yellow colour. The filament calls for no further description, except to say that it continues directly into the middle portion of the anther, between the two halves of which it can be traced as the *connective*. This is most easily seen on the side of the anther turned towards the centre of the flower, since the two halves or lobes of the anther face outwards and conceal the continuation of the stalk on this side. Each lobe of the anther contains two cavities called *pollen-sacs*, within which the *pollen* is formed. When the stamen is mature a longitudinal slit forms on either side of the anther, opening the pollen-sacs, and the pollen is shed as a somewhat adhesive, yellow, powdery mass. The formation of the pollen, which consists of isolated cells, is the function of the stamen.

In the centre of the flower a group of small green bodies will be seen. These are the *carpels*, and together they make up the region of the flower called the *pistil*. The numerous carpels are inserted separately on the upper part of the floral receptacle, and are much less leaf-like than the other parts of the flower. They are best seen on removing the sepals, petals, and stamens from a flower, or on cutting a flower in half. A single carpel can also be removed from the receptacle with the point of the knife, and will be found to have been attached by a narrow base, above which it suddenly widens out to narrow again to a fine tip, which curves outwards. The whole carpel is flattened laterally; the lower part has a pale green colour, while the narrower upper portion is yellowish. Each carpel is really a hollow body, and corresponds to a leaf bent round so as to enclose a cavity. Within this cavity is a small stalked body, which is destined later to develop into a seed. This little body is the *ovule*, and can be seen with the lens through the translucent wall of the lower part of the carpel. With care it is possible to open the latter, and remove the ovule on the tip of the knife. The wider lower part of the carpel, within which the ovule is contained, is called the *ovary*, the narrower part above is the *style*, while the small rough tip to this is the *stigma*. The pistil of the Buttercup is thus seen to consist of a number of separate carpels, each of which encloses a single ovule.

Before the ovule can develop into the seed some of the pollen, which we have seen to be formed in the stamen, must be brought to the stigma. The pollen may be derived from the stamens of the same, or of another flower, and the process of transferring it from the anther to the stigma is known as *pollination*. Pollination is followed by other changes, into which it is unnecessary to enter here, but it must be understood that one of the two cells, which unite to give rise to the new plant in the seed, comes from the pollen grain, while the other is contained in the ovule. It is because these two cells must be brought together by the transfer of pollen to the stigma, and the processes that follow on this, that the reproduction effected by the flower is spoken of as sexual, and contrasted with vegetative reproduction. The

flower, as was stated above, is a shoot specially modified for the purpose of sexual reproduction.

Once the need of pollination has been recognised we are in a position to consider the use of the brightly coloured petals and the nectar in the flower. The uses of the other parts will have been already realised ; the sepals serve to enclose and protect the other parts of the flower in the bud, while the stamens form the pollen, and the carpels enclose and protect the ovules. Why has the Buttercup, like so many other flowers, an apparently useless display of brightly coloured petals ?

Since the stamens and carpels are close together in the same flower it might have been expected that the pollen would fall directly on the stigmas. This is, however, comparatively rarely the case, and many of the features of flowers are to be explained as rendering likely the carriage of pollen from the stamens of one flower to the stigma of another. Sometimes this *cross-pollination* is effected by the wind, but in the case of most conspicuous flowers the pollen is carried from flower to flower by the insects visiting them in search of food. Everyone knows the way in which bees, butterflies, flies, and other insects visit flowers, and has probably realised that they get honey and pollen from them. The insects may feed off the nectar or pollen, or they may in the case of bees carry it home to be stored, or to feed their young. In visiting the flower the insect gets some part of its body dusted with pollen, and on going to another flower of the same kind may rub this on the stigma, and so pollinate the flower. The variety in form and colour of flowers finds its explanation in the complicated and beautiful adaptations which exist between the flower and its insect visitors. These will be pointed out in each example described.

The Buttercup has a relatively simple method of pollination. Many insects, especially flies, visit the flower, the bright colour of which makes it conspicuous from a distance. They may either feed off the pollen, of which a large quantity is formed in the numerous stamens, or may suck the nectar from the little pocket-like nectaries at the base of each petal. The provision of this food is not an indiscriminate charity to the insects on the part of the plant. While feeding, the insect visitors get

dusted with pollen, and, while they may rub some of this on the stigmas of the same flower, they are more likely, on going to another flower, to effect cross-pollination. Cross-pollination is often more advantageous, and many of the arrangements found in flowers appear to render it likely or to prevent *self-pollination.*

After pollination has been effected the sepals, petals, and stamens of the Buttercup wither and fall off, but the group of carpels remains on the receptacle, and enlarges to form the fruit. Before considering this, however, it will be useful, as a preliminary to the study of particular examples, to form some idea of the chief modifications which are found in flowers.

The Buttercup is a particularly good flower to start with, for all its floral-leaves are inserted distinct from one another on the receptacle. In most flowers, however, the distinctness of the parts is modified by their union in various ways and degrees. Examples will be met with in the plants described later. Here it is only necessary to make clear the nature of the modifications to be expected. In the first place, parts of the same kind inserted at the same level on the receptacle, *i.e.* belonging to the same whorl, may be more or less completely united together. When the sepals are joined in this way the calyx appears as a tubular or bell-shaped structure. This has usually a number of free teeth or lobes projecting from the margin and indicating the number of the united sepals. The petals are even more commonly united to form a tubular corolla, and the stamens are sometimes joined together in the same way. The union in all these cases is not to be looked upon as a joining together of distinct and separate, fully grown parts. It results from a modification in the development of the flower, which the diagram in Fig. 54 will make clear. The petals, for example, arise as little outgrowths of the receptacle. When they are distinct the further growth is limited to the base of the outgrowth. But when growth spreads to the region of the receptacle between the petals these

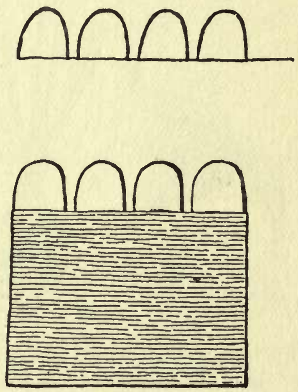


FIG. 54.—Diagram to illustrate the mode of union of parts of the same whorl.

are raised upon a tubular growth, and thus appear to be united. The parts developed from the original outgrowths give rise to the free lobes on the margin of the tubular part of the corolla.

It is comparatively rare to find the carpels distinct from one another as in the Buttercup. They are usually less numerous than in that flower, and form a single whorl, the number of carpels being the same or smaller than that of the petals or sepals. They may be more or less completely united to form a single pistil. Sometimes only the lower parts are joined, the upper portion of the ovaries as well as the styles and stigmas being separate. Often there is a single ovary from which the free styles project, their number indicating the number of carpels making up the ovary. When the union is most complete the styles and stigmas are also joined, and the number of carpels is not distinguishable, or is only indicated by the lobing of the stigma (Fig. 55).

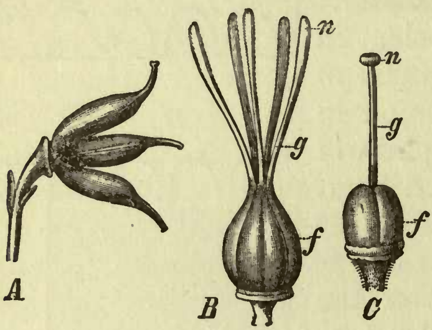


FIG. 55.—The pistil of—A, Monkshood; B, Flax; C, Tobacco Plant. *f*, ovary; *g*, style; *n*, stigma. (From Strasburger's *Lehrbuch der Botanik*.)

While considering the union of the carpels, attention must be directed to the construction of the ovary and the different positions in which the ovules are borne. When the carpels are separate and distinct, as in the Pea or the Marsh Marigold, it is often easy to see that each corresponds to a leaf bent round so that the margins meet, and thus enclosing a cavity. In such cases the ovules are borne along the united margins, and thus stand in a row along the junction which faces the centre of the flower (Fig. 56, A). The Buttercup has a carpel of this kind, but this contains a single ovule only. When joined together to form a single ovary, the latter has often as many chambers as there are carpels, and the position of the ovules in them corresponds to their position in the single carpel. Examples of this are the Tulip or Wild Hyacinth, where the pistil is formed of three carpels (Fig. 56, B). In other cases the carpels are joined edge to edge to enclose the single cavity, and then the ovules usually spring from the wall of

the ovary along the lines of junction of the carpels. The pistil of the Violet is an example of this (Fig. 56, C). Another important type of attachment of the ovules is when, as in the Primrose, the ovary has only one cavity, but the ovules are borne on a projection from the base of this and do not spring from the walls (Fig. 56, D). These examples do not in any way exhaust the variety in the construction of the ovary, but will serve to indicate the importance of examining it very carefully in studying any flower. This is also important as enabling the construction of the fruit to be understood.

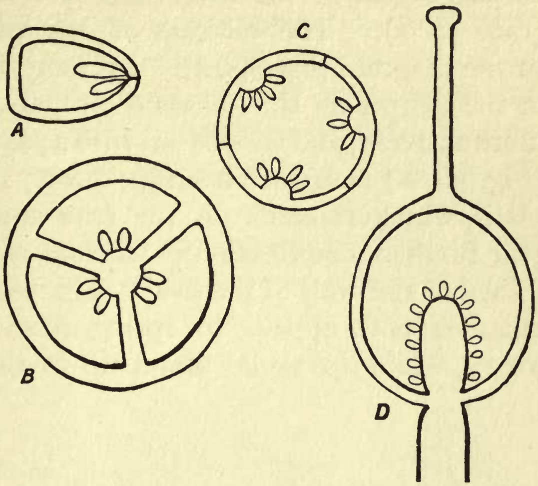


FIG. 56.—Diagrams of arrangements of ovules in the ovary. A, Marsh Marigold; B, Wild Hyacinth; C, Violet; D, Primrose.

In the same way, as parts of the same whorl may become united, parts of two succeeding whorls may be joined by being lifted up on a common zone of growth. The most common case of this is when the stamens appear to be attached to the inner face of the petals, or to spring from the inside of the tube of the corolla. The diagram (Fig. 57) will make this clear, and examples will be met with below, in the Primrose, the Periwinkle, and many other flowers.

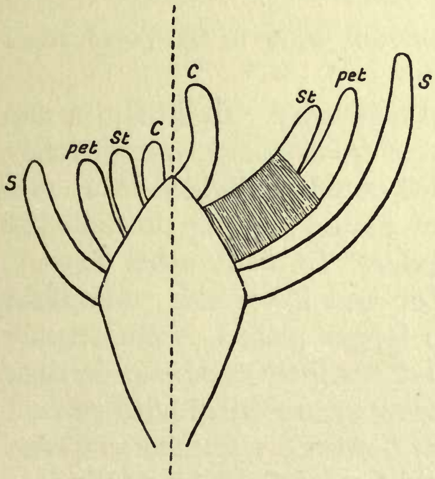


FIG. 57.—Diagram to illustrate the mode of union of stamens and petals. *s*, sepal; *pet*, petal; *st*, stamen; *c*, carpel.

Another important series of differences in the construction of flowers depends upon the

unequal growth of the floral receptacle. The receptacle in the Buttercup is conical, and the sepals, petals, stamens, and carpels stand in the order named from below upwards upon it (Fig. 53, B). The relation of the various parts is that shown in the diagram (Fig. 58, A). In many flowers, however, the region of the receptacle that bears the sepals, petals, and stamens grows more actively, and widens out into a plate-like (Fig. 58, B) or cup-like (Fig. 58, B′) structure bearing these parts on its edge around the pistil, which remains on the true summit of the receptacle. A still further modification is reached when the hollow receptacle is joined to the wall of the ovary (Fig. 58, C). The sepals, petals, and stamens now appear to spring from the upper surface of the ovary, while the styles stand up in the centre of the flower. In

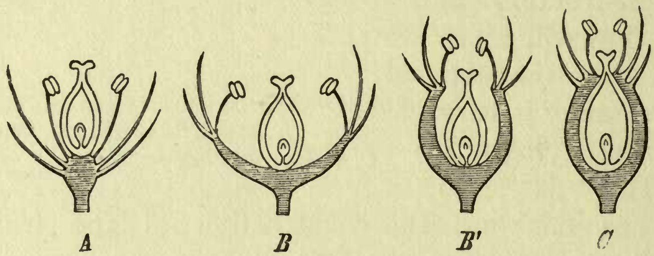


FIG. 58.—Forms of receptacle of the flower. (From Strasburger's *Lehrbuch der Botanik.*)

this case the ovary is spoken of as *inferior,* while in the two former cases (A and B) it is termed *superior.*

Flowers also differ in their general symmetry. In the Buttercup and many other flowers the floral leaves are disposed symmetrically around the centre of the flower, which could be divided into equal and similar halves by a number of planes passing through the centre. Such flowers are called *regular.* In many other flowers, however, we can recognise an upper and lower side, and right and left halves. The parts are no longer placed symmetrically around the centre, but differences in either their number or in their size and shape lead to the flower being symmetrical with respect to one plane of division only. Such flowers are termed *irregular,* and many of the flowers most highly specialised in relation to their insect visitors will be found to be of this kind. The Violet, the Dead-Nettle, and the Orchid are good examples from among

those described below. The plane of division separating the flower into similar halves usually runs from front to back of the flower; in a few cases it lies at right angles to this. Insects visiting irregular flowers are usually induced to approach the flower from one particular direction. On taking up their position in the flower they touch the stamens and stigmas with particular parts of their body, and the arrangements for cross-pollination can thus be made more precise. Details will be found under the examples described.

We may now return to the consideration of the *fruit* of the Buttercup (Fig. 59), which was seen to be derived from the group of carpels after the other parts of the flower have fallen. The carpels enlarge, as do the young seeds within them, and the seed practically fills the whole space within the carpel. When ripe the seed is protected by the firm dry carpel. The product of development of the whole pistil may here be called the fruit, and that of the separate carpels fruitlets. The latter at maturity become detached from the receptacle and are shed singly. Since each fruitlet has only one seed within it, the wall does not burst open to liberate the seed, which remains, until germination, protected by the carpel.

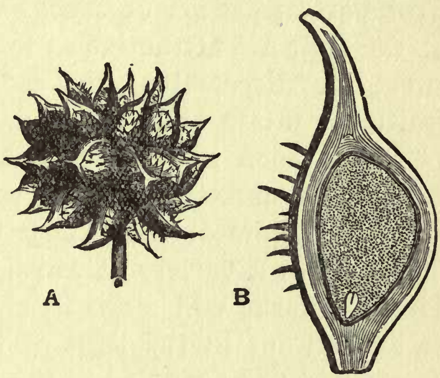


FIG. 59.—A, Fruit of Buttercup; B, single fruitlet cut in half, showing the seed in which the embryo plant and the mass of food material can be distinguished. (After Baillon.)

The *seed* of the Buttercup (Fig. 59) consists of a covering called the seed coat, a mass of food material and a very small embryo plant. Under suitable conditions of moisture and warmth the little plant commences to grow; the seed is said to germinate. Growth is at first at the expense of the food material stored beside the embryo in the seed. When the first roots have penetrated the soil, and the first leaves are exposed to the light, the little plant can obtain and manufacture food for itself.

From what was said above, as to the differences between the

pistils of various plants, it will be evident that great differences will be found in the construction of the fruits derived from them. Details will be found under the plants described. A word must, however, be said introductory to their study. The fruit, like the flower, must be studied from two points of view. Its structure must be examined in the light of that of the pistil and the other parts of the flower taking part in its formation, and the way in which the fruit is of use in the life of the plant must also be considered. Put broadly, the fruit has to protect the developing seeds and to ensure their distribution, so that they will have a chance of lodging in suitable situations and grow into new plants. Fruits are either *dry* or *succulent*. In the latter case, when parts of the fruit are attractive as food to birds or other animals, these effect the dispersal of the seeds. When the dry fruits or the fruitlets contain only one seed, as in the Buttercup, they do not as a rule open to set the seed free. When, however, the seeds are more numerous they are usually shed from the fruit, which opens to allow of this. Dry fruits or seeds are adapted to be dispersed in a variety of ways, very often by means of the wind. These remarks will serve to show that the study of fruits must be carried out in the light of their uses, as the structure of the flower had to be studied in the light of the method of pollination.

The seeds of plants and their germination are treated of in another section of this work, and may be dismissed with brief reference here. The seed, which varies greatly in size, is always enclosed in a seed-coat, which may be thick or thin and variously sculptured. Within the seed-coat is a small plant which often shows the young root, shoot, and the one or two seedling leaves. This embryo plant may entirely fill the seed-coat, as in the Pea, or along with it may be found a tissue containing food material, as in the Buttercup. In the former case food is usually stored in some parts of the embryo, usually the seedling leaves, which are enlarged for the purpose. The start in life of the plant can sometimes be followed in seedlings collected in the wild state in the neighbourhood of the parent, but usually it is necessary to collect and sow the seeds.

We have now passed in brief review the main features that can be observed without special apparatus in any Flowering

Plant. It will be of use to summarise the points regarding which information should be sought in studying any plant. A scheme such as the following will assist, though it should not limit, our observation, and will ensure its being carried out methodically.

1. The general appearance of the plant; the situation in which it grows; its duration of life.
2. Root-system: existence or not of a tap-root; branching; origin of additional roots from the stem; whether the root extends deeply or spreads out in the superficial layers of soil.
3. The vegetative shoots: underground shoots must be carefully distinguished from roots, and studied; the features of the stem; the arrangement of the leaves; branching of the shoot; the form of the leaves.
4. Means of vegetative reproduction, if any.
5. The inflorescence: its branching; presence and form of the bracts.
6. The flower: calyx, corolla, stamens, pistil; shape of floral axis or receptacle; symmetry of flower, regular or irregular; presence of nectaries and their position; method of pollination.
7. The fruit: construction; mode of dispersal of the seeds.
8. The seed: germination; the seedling.

Advice as to Practical Work

The importance of practical work has been emphasised above. Observations on Flowering Plants of the kind described here can be carried out with the help of very simple apparatus, and in any dwelling-room or even in the open beside the plant. The simplicity of the work is one of its great advantages in the teaching of Nature Study. Interest in the life of the plant and patient observation are of more importance than any apparatus, and the great aim of the teacher should be to awaken and sustain the interest of his scholars. Given this interest, the thorough study of one or two plants will lead to observations being made on others. The descriptions of common plants given below are not exhaustive, but will direct the attention of the student to the main features of the plant. They should be used as a help in the practical study of the plant.

The first methodical examination of a plant is best made in a room, and it is advisable to have a bare unpolished table, or to protect the surface or table-cloth so that the necessary mess can be made. The first study of the plant will probably disclose some difficulties which can only be cleared up by examining further specimens or plants at another stage of their growth. Many points also regarding the mode of growth, the method of pollination, the dispersal of the seeds, etc., will have to be inquired into by studying the plants as they grow in nature. It is well to start, however, with specimens of the plants collected and brought home, so that they can be examined with comfort and the results methodically recorded.

A word must be said as to *collecting material.* If possible this should be done by the student himself, since this ensures a general knowledge of the situation and mode of growth of the plant. Small plants should be carefully dug up so as to obtain the root system uninjured. This may be done with a stout knife, but a trowel or digger is better for the purpose. A number of specimens should always be collected, and should, if possible, show flower-buds, flowers, and fruits. When flowers and fruits cannot be obtained at the same time, and indeed in every case, the plant should be studied at different seasons. In the case of larger plants, such as shrubs and trees, it is obviously impossible to collect the whole plant. Shoots showing as much as possible of the mode of growth and bearing flowers or fruit should be taken. The branching and the general form of the plant should be studied in living specimens in position, and advantage should be taken in the case of trees of any uprooted specimens to make notes on the root system. To carry the specimens home and to keep them fresh, they are best kept in a tin box, and the collecting-tin or vasculum of the shape which tradition has sanctioned will be found the most convenient thing for the purpose. The vasculum should be of good size, large enough to take in complete specimens of any moderate-sized herbaceous plant, and should be fitted with a strap by which it can be slung over the shoulder, leaving the hands free. Many plants keep better for a day or two in the vasculum than when removed and put in water.

The *apparatus* needed for the dissection and examination of the plant is very simple. A sharp penknife, kept for the purpose, or one or two scalpels with straight blades, are needed to dissect flowers, buds, etc. Another essential both for examining plants at home and in the field is a magnifying-glass or pocket-lens. This need not be of an expensive type ; for all ordinary purposes the single or triple lenses in vulcanite mounts, sold for the purpose for half a crown or less, will do admirably. A pair of forceps for holding small parts of the plant when examining them, and one or two needles mounted in wooden handles, are useful additions to the furniture of the working table.

To record what has been seen and to assist accurate observation, it is necessary to make notes, and especially to draw the parts of the plant. For this purpose the student should be provided with a note-book of good paper without lines, with pencils of various degrees of hardness, including a hard one for making definite outlines, and with indiarubber. The drawings that should be made are not pretty pictures of the whole plant, but detailed outline drawings of the separate parts. Accuracy rather than beauty is the object of drawings for this purpose. All the drawings should be on a good scale, small parts being drawn several times their actual size to allow of the details made out by the lens being recorded. Clear outline drawings are the most useful, and shading should only be employed when it is really necessary to make the form clear. Drawings of this kind are of special value for the teacher, since they are an excellent preparation for illustrating the subject on the blackboard. Besides the value of these drawings, as a record of what the student has seen for himself, the attention to details which is necessitated by making a good drawing leads to features being noticed that would otherwise be passed over. Thus even when the drawing is not preserved the making of it is a valuable assistance in accurate observation. The drawings should not be crowded in the drawing-book. A brief statement of what is represented should be written beneath each, and all the parts represented in the drawing should be carefully labelled. If this labelling is done fully it almost does away with the need of making detailed descriptive notes, though, when the plant has been fully studied,

a full description of what has been observed and of the chief features of interest will be of use to bring the facts together and for future reference in teaching.

When the form of parts of the plant is complicated it may be found helpful not merely to draw the object from several points of view, but to model it. The preparation of modelling clay known as plasticine is readily obtained and serves admirably for this.

Although *the making of a collection of dried plants* is not in any way a chief end or object in such studies as these, some well chosen specimens will be found of great use along with drawings and notes for future reference. While drawings must be depended on for details of the flower and fruit, such features as the general appearance or habit of the plant, the arrangement and shape of the leaves, the branching and the structure of the inflorescence may all be shown in a well-arranged dried specimen. It will be found useful if, without making any haste to amass a collection, specimens are carefully selected and preserved of each plant that is studied. To assist the student in doing this, a brief account of how to dry plants may be given !

Careful selection should be exercised to obtain an individual plant which shows as many as possible of the characteristic features clearly. It should be brought home without crushing or injury, and arranged so as to display the parts naturally on a sheet of drying paper. There is a special kind of absorbent paper sold for this purpose, but sheets of thick blotting-paper do admirably, and ordinary newspaper may be made to serve. The sheets should be of good size ; 17 inches by 11 inches is ample. It is essential that the paper should be thoroughly dry, since the object is to absorb the juices of the plant quickly. Having arranged the specimen on the sheet, beneath which should come half a dozen similar sheets, it is to be carefully covered with another sheet of paper. Upon this come several other sheets, and then, if desired, another specimen, and so on. When the pile is complete it should be subjected to light but steady pressure. This is best done by enclosing the papers between two boards or wire frames, placed above and below the bundle and held in position by a strap. Books or bricks can be piled upon the upper board,

and the whole left for twenty-four hours. The papers should then be changed for the first time, each specimen being lifted and carefully arranged again on a new and dry sheet. In its limp condition this is more easily done than when the plant was fresh, and great care should be taken to place the parts of the plant in the positions they are to permanently occupy. A longer interval, depending on the succulence of the plants, may elapse before the next change of papers, and after two or three changes the plants may be left for a week or two until thoroughly dry.

They should then be mounted on sheets of stiff white paper a little smaller than the drying sheets; 16 inches by 10 inches is a convenient size. After laying the plant in the right position on the sheet it can be fastened down with strips of gummed paper, crossing the stems and leaf-stalks at intervals. If necessary a touch of strong gum will serve to fasten down any slacker portions. The sheet should then be labelled with the scientific name of the plant, its English name, the situation and locality in which it was found, and the date at which it was collected. This is all that is done with ordinary specimens for a collection, but in the case of plants which have been carefully studied, the specimen, as it lies on the sheet, may be treated like a drawing, and all the chief parts labelled. Notes and sketches of details of the flower or other features not shown in a dried specimen may, if it is desired, be added, and the specimen will thus serve as a fairly complete record of the observations made. Such specimens are not only useful for reference, but may be of great value in teaching. Thus when a plant is being studied in its winter condition the specimen will show what it was like when in flower in the summer.

While thorough dissection and study of specimens of a plant are necessary, and dried specimens are useful for future reference, it must never be forgotten that these are merely aids to the understanding of the plant as a living being growing in its own place in nature and having a definite life-history. Every opportunity should be taken of *observing the plant growing in natural surroundings*, and at various times of the year. This applies also to cultivated plants, though in them the competition with other plants cannot be directly studied. Every plant in a wild state is in competition with its neighbours, and should be regarded from

this point of view. Sometimes the causes of success can be traced in the vegetative growth of the plant, or in its means of vegetative reproduction. The success and spread of the Daisy in a lawn, for example, or of the Creeping Buttercup on waste ground, are illustrations of this. The use of the tubers of the Potato to the plant can only be realised when growing plants are examined, and the value of this mode of reproduction to the plant when growing wild can be inferred. Another important set of observations that must be made in the open are those on the way in which flowers are pollinated, and on the relations between flowers and insects. While the probable effect of insects visiting a flower can be made out by dissecting the flower at home, only patient observation can show whether insects visit it, what insects come, and how they behave when feeding. This work demands time, but is of the greatest interest. The dispersal of seeds and fruits also affords many opportunities for open-air observations.

Another direction which practical work should take is the cultivation of selected plants, and the study of their whole life-history. Easily grown plants should be chosen, and should be planted either in a small school garden or, if no ground is available, in pots or boxes. The Pea grown from seed, the Potato grown from the tuber, the Crocus from its corm, and the Tulip or Narcissus from the bulbs, are examples of very easily cultivated plants from among those described below. A sufficient number of plants should always be started to allow of specimens being dug up at intervals and examined at various ages. The study of one or two plants in this way will indicate the sort of observations which can be made on the life-history or annual history of others in the wild state, if they are examined periodically throughout the year.

The study of single plants on the lines that have been indicated will lead, on the one hand, to the recognition and collection of the flowering plants of the locality, and to their identification with the help of a flora,—that is, to the study of the classification of plants. On the other hand, it will form a valuable preliminary to the study of plant communities, which is treated of in another volume of this work.

CHAPTER VI

Spring Flowers

The Lesser Celandine—The Lady's Smock—The Sweet Violet—The Primrose—The Lesser Periwinkle—The White Dead-nettle—The Dandelion—The Tulip—The Field Wood-rush—The Daffodil—The Crocus.

The Lesser Celandine (*Ranunculus Ficaria,* L.).

The Lesser Celandine, as its scientific name indicates, is a close relation of the yellow Buttercups which flower later in the season. One of the Buttercups has already been described, and a comparison of the Lesser Celandine with this will show admirably in what different ways closely related plants are fitted to meet the needs of their life, and of competition with other plants. That the Lesser Celandine is well adapted to the conditions under which it grows is shown by its abundance, especially in shady and marshy spots, under trees and by streams. Considerable tracts of soil may be covered by it, and be bright with its yellow flowers, which appear in March and April and are over early in the summer.

The Lesser Celandine is a perennial plant, and, like many other spring flowers, grows rapidly early in the year at the expense of food materials manufactured by the leaves of the preceding season, and stored in the subterranean parts for this purpose. The underground parts will be found to be specially modified for the storage of food material, so that the specimens to be examined should be carefully dug up and their roots washed free from soil. A superficial inspection of a whole plant at the time of flowering (Fig. 60) will show that in addition to a number of thin branched roots of ordinary appearance there are a number of club-shaped tuberous roots clustered at the base of the stem. The shoot has a number of foliage leaves crowded together at the lower part, while above this the internodes are elongated and the shoots branched.

As in the Buttercup, the main stem and each branch ends in a flower. All these parts require to be examined in detail.

The root system consists of a number of roots springing, not from a main root, but from the base of the stem. The slender branched roots that extend into the soil around, and obtain from it the water and salts needed by the plant, call for no special description. The storage roots, which form a cluster diverging from the base of the plant, are more or less numerous, according to the size and strength of the latter. They are unbranched, club-shaped bodies, widening gradually from the point of attachment to the stem. In a plant examined in May two sets of these tuberous roots can be distinguished. One group consists of fully grown roots of a brown colour. Many of these have a wrinkled or shrivelled appearance. The roots of the other set, which appear to spring from a slightly higher level of the stem, are plump and firm, often whitish, and not fully grown. The older roots are those in which the food, which has been used up in the growth of the shoot and flowers of the plant, was stored. Their use is now over, since, as the wrinkled appearance indicates, they have been depleted of the substances stored in them and they will perish and decay as the season advances. The new series of tuberous roots will be stored with food material during the early part of the summer, and when the shoots die down will remain in the soil until growth again starts at the expense of the food they contain.

FIG. 60.—Whole plant of the Lesser Celandine, in flower. (After Farmer.)

In most cases a single bud develops into the leafy shoot of the plant. In specimens examined very early in the year this will be found in an unexpanded condition. As it unfolds it is seen that on the outside are several whitish scale leaves and following them come a number of foliage-leaves, which are borne

close together on the stem, the internodes not elongating in this basal region. These foliage leaves thus form a cluster springing from just above the root. Above their insertion, in plants which are large enough to flower, the shoot continues its growth, and here the internodes are more or less elongated. Usually there is an internode above the basal leaves, and then come two leaves inserted one above the other but close together. The stem may bear two more leaves, but above them continues as a long, leafless flower-stalk supporting the first flower, which thus terminates the main axis of the shoot. The plant usually bears more than one flower, and the later flowers terminate lateral branches, which spring from the axils of the leaves on the main shoot. In the axils of the leaves borne by the branches shoots of a third order stand, and also end in flowers.

The foliage-leaves of the Lesser Celandine have a wide sheathing base, a long leaf-stalk, and a heart-shaped leaf-blade. This is of a rather dark green colour above; in some varieties it has paler blotches. Like the rest of the plant, the leaves are hairless. The leaves borne on the flowering shoots are similar, but have shorter stalks. The scale leaves correspond to the enlarged sheaths of leaves, the upper portion of which is not developed.

In the axils of the scale leaves at the base of the shoot a number of small buds are developed. There are several of these minute buds in the axil of each scale, so that a considerable number surround the base of the shoot. The buds remain very small, but from each a single tuberous root develops. These do not therefore, like the ordinary absorbent roots, spring directly from the main stem, though, since the buds are not easily seen, they appear to do so. In a flowering plant in April or May the scale leaves have perished, and the tuberous roots in connection with their axillary buds have attained a considerable size. The relation of the root tubers of the Lesser Celandine to the shoot is thus more complicated than appears on first sight.

Buds are also formed in the axils of the basal foliage leaves which succeed the scale leaves. Usually only one of these, that in the axil of the uppermost leaf, attains any size, but sometimes more than one develops. The enlarged bud is destined to form next year's shoot, and has the structure described above. At

the end of the season, when the flowering shoots die down, there is left in the soil the group of tuberous roots in relation to the buds at the base of the stem, and above them this bud or buds. Normally the whole group of storage roots is subordinated to the requirements of the single bud growing into the new shoot, and the small bud at the base of each root-tuber does not develop.

Should, however, a root-tuber become detached from the plant, it carries with it the small bud from the base of which it sprang. Under these conditions, which must often happen in nature, the root-tuber serves as a means of giving rise to a new individual, and thus reproducing the plant vegetatively. The plant is of course small, and usually only puts up a single foliage-leaf and forms one new tuber, but in the course of years grows larger, forms more numerous tubers, and then sends up a flowering shoot. Young plants developed from separated root-tubers are constantly found in the neighbourhood of the larger plants.

On plants growing in shady situations tuberous storage roots are often developed in connection with buds in the axils of the leaves higher up on the flowering shoot. In these cases the relation of the storage root to the bud is readily made out, and since the buds, each attached to a root filled with food material, are necessarily isolated by the decay of the shoot and scattered on the surface of the soil, the plant may be largely spread in this way.

The construction of the underground parts of the Lesser Celandine thus stands in relation, in the first place, to the continuance of the individual plant from year to year, and secondly, to the vegetative reproduction of the plant. Apart from the growth of new plants from seeds, this can take place : (i) by the production from a plant of more than one flowering shoot each of which will form its own group of tubers at the base ; (ii) by the detachment of root-tubers from the base of a plant ; (iii) by the natural isolation of the root-tubers formed higher up on the shoot. While the increase in size of the areas occupied by the plant may be assisted in all three ways, the spread of the plant to any distance is most likely to be effected vegetatively by the tubers formed on the aerial shoots.

The position of the flowers at the end of the main stem and

its branches, and the branching of the flowering shoot or inflorescence having been mentioned above, it remains to describe the flower itself (Fig. 61). It will be found to be constructed on an essentially similar plan to that of the Buttercup. On the outside are three greenish-yellow sepals, which enclose the flower-bud when small. Within the calyx come eight to twelve narrow strap-shaped petals, greenish below but bright shining yellow on the upper surface. Each petal has a small scale on its upper surface close to the attachment, and nectar is secreted in the little pocket formed by this. Within the petals come a large number of stamens, each with a yellow stalk supporting a relatively broad anther. The carpels are inserted separately, though closely crowded, on the summit of the conical floral receptacle. Each consists of a flattened green ovary bearing at its summit the rough stigmatic surface. If a carpel is carefully opened with the tip of a sharp knife or scalpel it will be found to contain a single ovule attached close to the base of the cavity of the ovary.

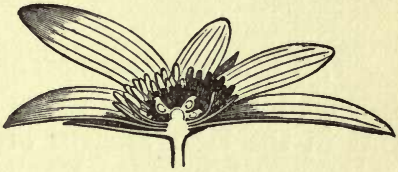


FIG. 61.—Flower of Lesser Celandine, cut in half. (After Baillon.)

As in the Buttercup, all the parts of this flower are inserted separately on the enlarged conical end of the flower stalk or floral receptacle, and stand in undisturbed succession on this. The calyx is lowest, while the pistil, composed of the group of separate carpels, occupies the summit of the receptacle.

The flowers close at night or in bad weather, but when widely open in the sunshine are very conspicuous, and are visited by many insects, chiefly small flies and bees. These may come in search either of the pollen, of which there is abundance formed in the numerous stamens, or of the nectar, which is hidden in the nectaries but easily reached. Since the stamens and stigmas are usually mature at the same time, there is every possibility that the flower may be pollinated with its own pollen, though in passing from flower to flower an insect may effect cross-fertilisation.

Many of the flowers do not develop fruits, though these can usually be found on careful search. The fruit is composed of

the enlarged group of carpels borne on the receptacle, from which the sepals, petals, and stamens have fallen. Each separate carpel develops into a fruitlet containing a single seed. When ripe the fruitlets, which do not open to liberate the seeds, become detached from the receptacle and scattered. The seeds do not germinate till the following spring, and the seedling is peculiar in having only a single cotyledon, although the plant belongs to the Dicotyledons which, almost without exception, have a pair of seed leaves.

The Lady's Smock, or Cuckoo Flower (*Cardamine pratensis*, L.).

This is a very common and abundant plant in damp meadows, to which its flowers sometimes give an almost continuous lilac tint in the later months of spring. It is one of a number of plants which bear the English name of Cuckoo Flower, doubtless because they are in flower at the season when the note of the Cuckoo is heard. The case may be mentioned as an illustration of the disadvantage of only knowing the English name of a plant. There is only one plant to which the scientific name *Cardamine pratensis* applies, and this makes reference easy and certain. Of the two English names of this plant, Lady's Smock is to be preferred as avoiding the risk of confusion with other Cuckoo Flowers.

The plant is a perennial, growing up season after season, and a well-grown plant has a thick underground stem upon which the scars of the leaves of former years can be distinguished. In the axils of some of them are buds, which are often developed as lateral shoots. Numbers of fine white roots spring from the stem. At the base of each shoot are a number of closely crowded leaves, the stalks of which are longer than those of the leaves higher up on the stem. In the case of shoots which are not going to flower, and remain short, these are the only leaves present. One or more shoots, however, elongate, and after bearing a number of scattered leaves end in an inflorescence of lilac-coloured flowers.

If the underground stem is more carefully examined it will be found to bear the marks of the flowering stems of former

THE LADY'S SMOCK (*Cardamine pratensis, L.*).

years, and a little consideration will show that it does not represent a shoot which has grown continuously from year to year giving off lateral flowering branches. It is rather made up, as is the case with the underground stems of many herbaceous perennial plants, of the basal region, of each annual growth. The growth is always continued by a lateral shoot, since the main shoot has continued into the flowering stem.

The long-stalked leaves at the base of the shoot have wide sheathing bases, and in the axil of each is a bud. The leaf-stalk is slightly channelled above and convex below. It bears a number of pairs of small stalked leaflets, and ends in a similar but larger leaflet. The leaf-blade is thus not a simple or unbranched one, but is compound or branched. Since the leaflets stand on either side of a main stalk, they are called pinnæ, and the whole leaf is described as pinnate from the general resemblance to a feather. This is a very common arrangement of the leaflets in compound leaves, and may be compared with the similar disposition of the main lateral veins in many simple leaves.

The cylindrical flowering stem has distinct internodes separating the leaves borne upon it. These have practically no leaf-stalk, the lowest pair of pinnæ standing close to the leaf-base. The leaflets are long and narrow as compared with those of the lower leaves. In the axils of these leaves are buds, which may remain undeveloped, or in stronger plants grow out into branches ending like the main shoot in an inflorescence.

Above the uppermost leaf comes a bare region of stem, and toward the end of this the flowers are crowded together. Their association on a special region of the shoot renders the group of flowers more conspicuous than the flowers would be singly. The inflorescence here consists of a number of flowers borne laterally on the main stem. This does not itself end on a flower, but grows on, producing flowers in regular succession. The youngest buds are thus found at the top of the inflorescence, the lowest flowers being the oldest and the first to open. Though the flowers correspond to lateral branches of the main stem, no trace of the leaf which we might expect to find beneath each is left.

An inflorescence such as this, in which the growth of the main

axis, which does not end in a flower, is unlimited, may be contrasted with that of the Buttercup or Lesser Celandine (cf. Fig. 52).

Each flower consists of a flower-stalk bearing, in order from below upwards, the calyx, corolla, stamens, and pistil, which are crowded together on the end of the stalk or the floral receptacle. In the bud only the calyx, the sepals of which completely cover in and protect the other parts of the flower, is visible. The four sepals do not stand at the same level on the receptacle, but are arranged in two pairs. The sepals of one pair, those standing front and back in the flower, are narrower than those of the other pair, and the latter are also bulged out at the base. A little careful observation is needed to make out which pair is outermost, but if it is noticed which pair overlaps the other it will be clear that the narrower sepals are the lower ones, although the bulging downwards of the bases of the other pair suggests at first glance an opposite interpretation. The corolla is composed of four petals, which, unlike the sepals, all stand at the same level. Each petal stands above the interspace between two sepals. As will be seen if the sepals are removed from a flower, the petals are all quite distinct or free from one another. Each consists of an erect stalk-like portion of a greenish-yellow colour, and of a wider oval portion which is bent so as to stand almost at right angles to the lower part. The end portions are coloured lilac, the colour being more strongly marked in the veins, and the four petals diverge like the arms of a cross, forming the most conspicuous part of the flower. The lower portions of the petals are enclosed and held together by the erect sepals, so that a sort of tube which surrounds the other parts of the flower is formed by the calyx and corolla.

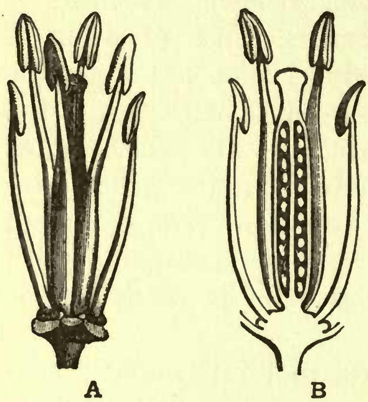


FIG. 62.—Lady's Smock. A, flower with sepals and petals removed, showing the six stamens around the pistil and the nectaries at the bases of the two short stamens. B, the same cut in half to show the construction of the ovary and the position of the ovules. (After Baillon.)

The parts within are best seen on stripping both the sepals and petals from a flower. This leaves the stamens standing on the floral receptacle around the pistil (Fig. 62). There are six stamens, two of which are shorter and stand farther away from the pistil, while the other four are longer and are grouped in two pairs. The two shorter ones stand lower on the receptacle, and are placed on either side of the flower immediately within the bulged-out sepals of the inner pair. Each stamen consists of a stout greenish stalk supporting the anther, the pollen sacs of which at first face inwards towards the centre of the flower. When examining the stamens the nectaries will be seen. The green rim around the base of each short stamen is a nectar-secreting gland, and a smaller nectary is present just below each pair of long stamens. The nectar secreted by these glands accumulates in the bag-like bases of the two inner sepals.

The pistil, which is borne on the summit of the receptacle and stands in the centre of the flower, presents difficulties to the observer on account of the small size of the parts. It is differentiated into a green ovary surmounted by a stigma which is slightly two-lobed. It is composed of two carpels joined together edge to edge, and the cavity of the ovary is divided into two by a longitudinal partition. In each half there are two rows of ovules lying against the partition (Fig. 62, B). [The structure of the pistil in the Charlock, where it can be more easily studied, should be compared.]

The flowers are visited by numerous insects, which come in search of the nectar concealed at the base of the flower. In sucking this they will place their heads between the stamens and the stigma, and on going to another flower may touch its stigma with the pollen-covered surface of their heads and so effect cross-pollination. The risk of direct self-pollination by the pollen from the anthers of the longer stamens falling on the stigma is lessened by the anthers making a half-turn outwards when the flower opens.

For some reason or another the flowers often do not set fruit. The construction of the fruit and its mode of opening, should specimens be found, will be understood from the description given in the following chapter of the fruit of the Charlock.

The plant is vegetatively reproduced by bulbils, *i.e.* small buds which develop at the base of some of the pinnæ of the lower leaves and grow up into new plants. These bulbils, while they spread the plant in its immediate neighbourhood, are not suited to disperse the plant widely, and this must result from seed-production.

The Sweet Violet (*Viola odorata*, L.).

A number of different species of *Viola* grow wild in Britain, while others with more showy flowers are in cultivation. The Dog Violet (*Viola canina*) and the Wild Pansy (*Viola tricolor*) are, together with the Sweet Violet, the most familiar of our wild species. The numerous garden varieties of the cultivated Pansy have sprung from a foreign species, *Viola altaica*, and other cultivated forms have been derived from *Viola tricolor*. All these plants, while differing in details, are sufficiently alike in their vegetative organs, in the construction of the flower, and in the mode of pollination for the description of the Sweet Violet that follows to be of some assistance in their study. The description will, of course, only apply in detail to the Sweet Violet.

Fig. 63.—Plant of the Sweet Violet. (After Baillon.)

This species grows wild on grassy banks in the southern counties of England, and is found less commonly farther north. It is also extensively cultivated for the sake of its scented flowers, which are on sale throughout the winter months and can thus be easily obtained for study. The plant is a perennial, and has a short, stout, woody stem which grows on at the summit year after year, producing each spring a rosette of leaves inserted close together on the stem (Fig. 63). A plant derived from seed has a main root, but in those which have been produced vegetatively in the manner described below the roots spring

from the stem. This also bears the withered bases of leaves of former years.

The leaves have long slender stalks, grooved on the upper face, which lift the heart-shaped leaf-blade well above the soil. The leaf-blade is simple, its margin being cut into small rounded teeth. The blade and stalk bear numerous short hairs. At the base of each leaf we find a pair of pointed stipules, which assist in the protection of the young parts in the bud.

In the axils of most of the leaves flower-buds are found, but in some vegetative buds develop. These grow into long creeping branches, which resemble the runners of the Strawberry. The internodes of these branches are long, and a small scale-leaf is borne at each node. Roots also spring from the stem. The end of the creeping shoot ultimately turns up and bears a rosette of foliage-leaves like those of the main plant. The runners thus serve to spread the plant vegetatively, and when they decay the new plants become independent at some little distance from the parent.

The flowers are borne singly in the axils of the leaves of the main shoot, and also in those of the creeping branches. Flower buds are already well developed in the axils of the foliage leaves in the autumn, but do not unfold till March or April. By this time the foliage-leaves of the preceding year are more or less withered, and the brightly coloured flowers borne on long stalks are conspicuous. The new foliage leaves are at this time beginning to expand. About half-way up the slender flower-stalk two small leaves or bracteoles will be found. Just below the flower the stalk is sharply curved, so that the flower stands horizontally or is directed obliquely downwards. The curvature takes place before the flower opens, and is always directed so as to cause the flower to face the strongest light. The flower itself (Figs. 63, 64) is an irregular one, so that, as borne on the flower stalk, we can distinguish an upper and lower side and right and left halves. The very complex and beautiful arrangements to favour cross-pollination by insects can only be understood after specimens of the flower have been carefully dissected.

The sepals are five in number, and as usual are of a green colour. One of them stands in the middle line at the back of

the flower. The bases of the sepals are prolonged backwards as short flaps. The five petals alternate in position with the sepals, so that one stands in the middle line in front, while a petal stands to either side and two form the back of the flower (Fig. 63). The petal in front is the largest. It is produced backwards as a hollow sac or spur, which projects between the two anterior sepals, and lies beneath the flower-stalk (Fig. 64, A). The spur is slightly flattened from side to side. This petal, the free margin of which is slightly notched, forms a lower lip to the flower. The lateral petals widen out from the narrow stalk-like basal part and form the sides of the flower. Each has a small tuft of white hairs about half-way up on its inner face ; the use of these will be apparent later. The two petals at the back of the flower are narrower, and bend backwards when the flower has opened. All the petals are coloured a beautiful violet blue, which is paler near the base and deeper in the expanded portions. The veins of the petals, especially of the one in front, are more deeply coloured, and form a system of lines converging into the opening of the flower.

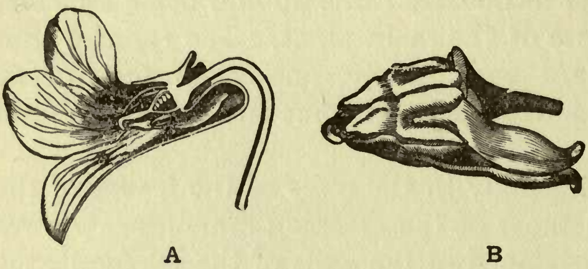


FIG. 64.—Sweet Violet. A, flower cut in half ; B, stamens and pistil after removal of the sepals and petals. (After Baillon.)

There are five stamens alternating in position with the petals. The form of the stamens will be best studied if the sepals and petals are carefully removed from a flower (Fig. 64, B), but their relation to the corolla must be studied in an uninjured flower. The stamens have extremely short stalks, and their anthers are very broad and flat. Above the anther, which has a pale yellow colour, the connective is continued as a triangular orange flap. The anthers stand close around the pistil, and touch by their edges, as do the triangular connective flaps, the tips of which bend in round the style. The stamens thus form a little box around the style, and the pollen is shed into this. The two lowest stamens have flat green processes springing from below

the anther (Fig. 64, B). These extend back into the spur of the anterior petal, which is adapted to contain them (Fig. 64, A) and are the structures which secrete the nectar. This accumulates in the spur.

The pistil is seen if the stamens are carefully removed. It consists of a small three-sided conical ovary continuing into a slender style, the tip of which bends down in front of the tips of the stamens. This bent tip is the stigma. The ovary is formed of three carpels, but has only a single cavity. The ovules are borne on the inner surface of the wall of the ovary in three rows, which correspond to the lines of union of the carpels (cf. Fig. 56, C).

If, having studied the form of all the parts of the flower, we take another specimen, and look at it from in front, the relative positions of the parts will be appreciated. The stamens and pistil will be seen to be enclosed by the basal portions of the petals, the tip of the cone formed by the stamens projecting in the opening of the flower. In front of this the style bearing the hooked stigma projects. Entrance to the spur, within which the nectar is contained, might be by the sides or beneath the staminal cone. The passage by the side of this is, however, filled up and blocked by the tufts of hairs projecting inwards from the two lateral petals. It is thus clear that the only easy way into the spur will be beneath the cone of stamens.

The flowers of the Sweet Violet are visited by a number of different kinds of insects, especially by bees, which come in search of the nectar secreted by the appendages of the two anterior stamens. Pollination is most satisfactorily effected when the insect alights on the anterior petal, and passes its proboscis beneath the stamens into the spur. In doing this it will touch the stigma first, and will then have pollen deposited on its proboscis, either by disturbing the stamens, when pollen will fall out of the box formed by the anthers, or from the groove in the petal, where pollen will have fallen. On the insect going to another flower the pollen on its proboscis will be deposited on the stigma, and the flower will be cross-pollinated. Pollination does not appear to result if the visits of insects are prevented, and the whole construction of the flower indicates its high specialisation for insect pollination. The shape of the irregular flower leading

to its being approached by the insect in a particular way, the converging lines on the petals pointing to the entrance to the nectary, the hairs on the lateral petals limiting the entrance to below the stamens, and the deeply seated nectar all find their explanation in the light of a knowledge of the pollination of the flower. The arrangement of the stamens and stigma determine the special mechanism for shedding and receiving the pollen.

Only the first developed flowers of the Sweet Violet have the structure described above. A little later in the season, when the new rosette of leaves is unfolding on the plant, the flower buds give rise to small and inconspicuous flowers, which remain hidden among the leaves and do not open. These flowers are self-pollinated, the pollen from the stamens reaching the stigma, around which the anthers are placed. These flowers are thus always fertilised and set fruit, while the conspicuous flowers must be cross-pollinated by means of insects for this to take place.

FIG. 65.—Wild Pansy (*Viola tricolor*). Fruit opening by splitting into three valves.

The fruit of the Violet, whether developed from the large or the inconspicuous flowers, is formed from the pistil. The sepals persist around the base of the fruit, but the petals and stamens wither and fall off (as does the style) as the ovary enlarges. The fruit contains a number of smooth round seeds attached in three rows to the inside of the wall of the developed ovary. As the fruit ripens its wall becomes dry, and ultimately splits into three valves along lines midway between the rows of seeds. As the valves of the fruit dry their edges curl inwards. In the Sweet Violet this serves merely to loosen the attachment of the seeds, which fall off; but in other species, such as the Wild Pansy (Fig. 65), the seeds are thrown to some distance from the fruit. The smooth seeds are nipped by the infolding edges of the valve, and are jerked away, just as a smooth marble might be if nipped by the finger and thumb.

The Dog Violet will be found to resemble the Sweet Violet in many respects, and, like it, has both conspicuous and self-pollinated flowers which do not open. The Wild Pansy, on the other hand, has only conspicuous, insect-pollinated flowers. The

general mechanism is similar in all three flowers, though differences will be found in the shape and exact relations of some of the parts.

THE PRIMROSE (*Primula vulgaris*, Huds.).

In April and May the rosettes of large leaves, and the pale yellow flowers of the Primrose, are conspicuous on grassy banks and in copses, where the plants often occur in such numbers as to lend a definite character to the landscape. The Primrose is a perennial plant, so that the individuals persist in the same spot year after year, and by branching may form a small cluster of shoots. This branching, which may lead to an increase in number of individuals if the branches become isolated, is more marked in Primroses and their relations grown in rich garden soil. Such cultivated plants will serve for study, but it will be found better to use the smaller plants of the wild Primrose if these can be procured.

In a plant at the time of flowering (Plate), which has been carefully dug up and its underground parts washed free from the soil, the rosette of leaves, which was alone apparent above ground, will be found to be borne on a fairly thick underground stem. Further back this bears a number of pink swellings, which comparison with the leaves of the rosette will show to be the bases of the leaves of former seasons. These persistent leaf-bases closely cover the whole stem, and add to the bulk of the plant available for the storage of reserve food material. Numerous thick white roots also arise from the underground stem, and give off finer lateral roots, which extend on all sides through the soil.

The leaves forming the rosette have persisted since just after the preceding flowering period, when they expanded; they are now about to wither and to be replaced by a new set. Each leaf has a broad, thick leaf-base, a wide, ill-defined leaf-stalk, which is somewhat concave above and strongly convex below, and a large, oval leaf-blade. The leaf-stalk is continued as the well-marked midrib, which projects on the lower side of the blade and tapers towards the tip of the latter. Lateral veins spring alternately to right and left of the midrib, and they and also the finer

veins project on the lower surface. The surface of the leaf-blade thus appears wrinkled; it is deep green above and paler beneath, where the veins bear numerous short hairs.

Within the circle of foliage leaves, that is, higher up on the stem, we come to a number of small pointed leaves which require to be carefully looked for. These are the bracts, and in the axil of each is a single flower. After the foliage leaves have been formed the stem bears the bracts, and with the production of the flowers that particular shoot ceases to grow. Provision is, however, made for the further growth of the plant. This is carried on by a lateral bud standing in the axil of one of the uppermost foliage leaves. This bud is now expanding, and the leaves, the blades of which are rolled backwards towards the midrib in the bud, contrast with the withered ones of the old rosette. The old leaves will shortly perish, and the bud will give rise to the rosette of leaves. These will remain until after the next flowering season, to be in turn replaced by a lateral bud. The underground stem is thus seen to be made up of the shoots of each year, and careful search among the leaf-bases will reveal the scars left by the group of flowers of each season, and enable the amount grown in each year to be determined.

The flowers in the Primrose are borne on long stalks which carry them clear of the leaves. In some close relations of the Primrose, such as the Cowslip, the whole group of flowers is carried up on a bare cylindrical region of the stem. This does not develop in the Primrose. The flower stalks are thin and cylindrical, and clothed with soft hairs. The flowers themselves are of two types which are borne on distinct plants, so that any individual bears flowers of one type only throughout its life. In general features the two kinds of flower correspond; they differ in the length of the style and the position of the stamens. The two kinds are familiar to gardeners, who call them "pin-eyed" and "thrum-eyed" flowers, and can readily be distinguished by looking at the face of the flower. In the pin-eyed or long-styled flowers the entrance to the tube of the corolla is occupied by a greenish globular stigma. The stamens are out of sight lower down. In the thrum-eyed or short-styled flowers the five anthers are seen at the entrance to

Photo by Henry Irving, Horley.

PRIMROSE (*Primula vulgaris*, Huds.)

the corolla tube, while the stigma borne on a shorter style is out of sight (Fig. 66).

Taking a long-styled flower (Fig. 66, B) for description we find it to consist of calyx, corolla, stamens, and pistil. The arrangement of these parts is, however, greatly modified by the union which has taken place between them, and the flower should be contrasted in these respects with such a flower as the Buttercup described above. The calyx is a pale green, tubular structure with its margin prolonged into five pointed teeth. These are the free tips of the five sepals, which are united together. The calyx has five ridges which continue down from the free teeth. The petals are also united together to form a tubular corolla. Their expanded tips are, however, separate, and bend almost at right angles to the tubular portion. The five lobes thus form the conspicuous face of the flower. They will be found to alternate with the teeth of the calyx. The greater part of the exposed portion of the corolla has a pale sulphur-yellow colour, but around the narrow entrance to the tube and on the base of the free lobes the tint is deeper, and this makes the entrance to the tube more prominent. The tubular portion is not the same width throughout, but suddenly widens about half way.

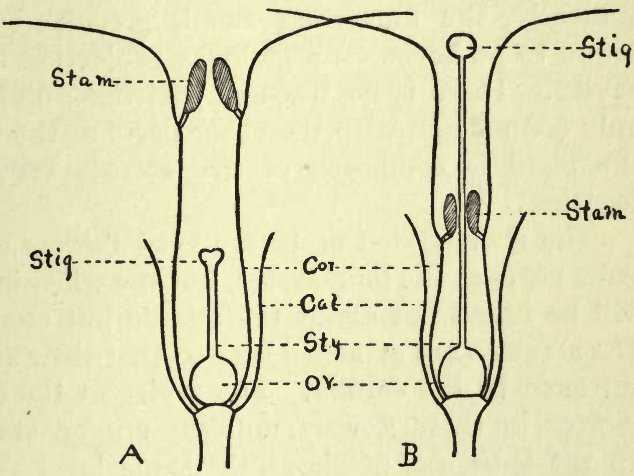


FIG. 66.—Primrose. Diagrams of relative positions of the parts in the thrum-eyed (A) and pin-eyed (B) flowers. *cal*, calyx; *cor*, corolla; *stam*, stamens; *stig*, stigma; *sty*, style; *ov*, ovary.

When the corolla is split open the widening is found to correspond to the place of insertion of the stamens, which are not borne on the receptacle of the flower, but are attached to the inner surface of the corolla. There are five stamens, which have very short

stalks. Each stamen stands opposite the middle line of a petal. The anthers open inwards, and expose the sticky yellow pollen.

In the centre of the flower, occupying the summit of the floral receptacle, is the pistil. This consists of a pale green, globular ovary, a long slender style like the shaft of a pin, and a small expanded stigma like the head of a pin. In the long-styled flowers the style is about the length of the tubular part of the corolla, and the stigma stands at the entrance to the tube. The surface of the stigma will be seen with a lens to be distinctly papillate and rough. When the ovary is carefully opened or cut through longitudinally, the numerous, small, greenish white ovules will be found to be borne on a globular projection from the base of the cavity. There is no trace of partitions dividing the latter, and only comparison with the other parts of the flower shows us that the pistil is composed of five carpels very completely united together.

The short-styled or thrum-eyed flowers are composed of the same parts as the long-styled, but the widening of the corolla tube will be found not about the middle but close to the upper end. The stamens are attached here so that their anthers project in the entrance to the corolla. The style, on the other hand, is much shorter in these flowers, and the stigma stands about half-way up the tube, *i.e.* at about the same level as the anthers in the long-styled flowers. The stigma is smoother and the pollen grains are larger in the short-styled flowers.

This remarkable development of two types of flower, both containing stamens and pistil but the position of the stamens in the one flower corresponding to that of the stigma in the other, occurs in a number of plants, the Primrose and its relations being the most familiar examples. In the Primrose it has been found that the best production of seed results when pollen is carried from stamens standing at the same level as the stigma receiving the pollen. This can only be brought about by a transfer of pollen from one type of flower to the other, that is, by cross-pollination.

While flowers may sometimes be self-fertilised, it has been found, by carefully watching the plants when in flower, that on favourable days a number of insects of different kinds visit the flowers in search of the nectar secreted at the base of the ovary.

Owing to the length of the corolla tube, only long-tongued insects can reach the nectar, and the visitors observed are long-tongued flies and occasionally humble-bees. When an insect visits a short-styled flower its head will be dusted with pollen. Should it now pass to a long-styled flower this pollen will be deposited on the stigma. At the same time, pollen will be deposited from the stamens of this form about half-way up the proboscis of the insect. When the latter visits a short-styled flower this region of the tongue will touch the stigma, which will thus receive pollen from stamens of the corresponding height.

The ovary of a flower that has been fertilised enlarges and develops into the fruit, which is surrounded by the calyx, while the corolla disappears The fruit contains a number of seeds, and opens, by splitting at the summit into ten short teeth. These roll back so that the seeds, as they become detached from the projection from the base of the seed-capsule, can fall out of the fruit.

The Lesser Periwinkle (*Vinca minor*, L.).

Two kinds of Periwinkle can be found wild throughout Britain, growing usually in the shade of trees in open woods or on hedge-banks. The Greater Periwinkle (*Vinca major*) is less common, but is commonly grown in gardens. The Lesser Periwinkle is well established in many places, and often covers the soil of open woods to the exclusion of most other plants. Neither of the species is probably a true native of this country, and there is reason to believe that the introduction of both the larger and smaller kind took place at the time of the Roman occupation of Britain. The plants flower in April and May, though occasional flowers can be met with in the autumn. Either will serve for study, the description being based on the commoner Lesser Periwinkle (Fig. 67).

This is a small perennial plant with dark green, glossy, evergreen leaves. It spreads largely by vegetative growth. At the level of the soil prostrate creeping shoots will be found. From some of the nodes of these shoots, which persist for years and become tough and woody, the buds grow up as more slender

erect shoots. These have elongated internodes, and at each node a pair of small, oval, foliage leaves with short stalks. The pairs of leaves alternate at successive nodes. On the horizontal shoots the leaves become twisted round so as to spread out in one plane, and appear as if they formed only two rows. From the persistent lower portions of the erect shoots lateral branches arise in succeeding years, giving rise to the clusters of erect shoots which spring at intervals from the creeping stems (Fig. 67). From these nodes numerous roots grow down into the soil. This mode of growth enables the plant to spread, and is largely responsible for its abundance and success in favourable situations.

FIG. 67.—The Lesser Periwinkle. (After Baillon.)

The flowers are borne singly in the axils of one or more of the upper leaves of the erect shoots. The shoot in the Lesser Periwinkle often has only one flower. This is borne on a slender green stalk, and consists of sepals, petals, and stamens in regularly alternating whorls of five, and of a pistil composed of two carpels. The construction of the flower is a complicated one, and should be carefully studied in several examples, since even the most minute features will be found to have their use in the pollination of the flower by means of insects.

The calyx is short as compared with the corolla. The sepals are united for a short distance at the base, but above this project as pointed green teeth. In the growing flower-bud the corolla in its closed condition projects far beyond the sepals, and shows clearly the twisted arrangement of the petals characteristic of this plant and its relations. When expanded it is seen to be composed of a tubular or funnel-shaped region, and of five lobes, which alternate in position with the sepals and correspond to the free ends of the petals. These lobes are peculiarly shaped, having one edge longer than the other. They diverge almost at right angles to the tubular portion of the corolla, and since they, as well as the tube, are of a bright violet-blue colour, render the flower conspicuous as it projects from the dark glossy foliage. The entrance to the corolla-tube is strengthened by a slight ridge of a paler tint, which gives the opening a pentagonal outline, each side of the pentagon stretching from the middle line of one petal to that of the next. Corresponding to the interspaces between the petals a white streak extends down the inside of the tube, and is indicated on the outside of the latter by a slight groove. The upper portion of the corolla tube is thus fluted (Fig. 68).

On looking into the tube the more internal organs of the flower are seen blocking the cavity about one-third way down. They form a whitish, ridged dome-shaped mass, which does not itself fill the cavity, but the space between it and the wall of the tube is occupied by downwardly directed white hairs springing from the latter.

To see the exact relation of the stamens and pistil to one another and to the corolla-tube, a flower must be carefully split in two (Fig. 68), or the corolla split up along one side and flattened out. The stamens will be found to be five in number, and to be attached to the inner surface of the corolla-tube opposite to the intervals between the petals, *i.e.* on the line of the white streaks mentioned above. The shape of the individual stamens is peculiar. The stalk springs from the inner wall of the tube a short distance below the widened upper end of the style, and slopes upwards and inwards beneath this. The stalk then bends sharply outwards until it touches the corolla tube, and then, bending inwards again, ends in the anther. Each of these has a wide flattened

connective, bearing the pollen sacs on the inner face and continuing above them as a flap-like appendage. These appendages roof over and conceal the pistil.

The shape of the stamens is only to be understood in relation to that of the pistil (Fig. 69). This consists of two carpels forming

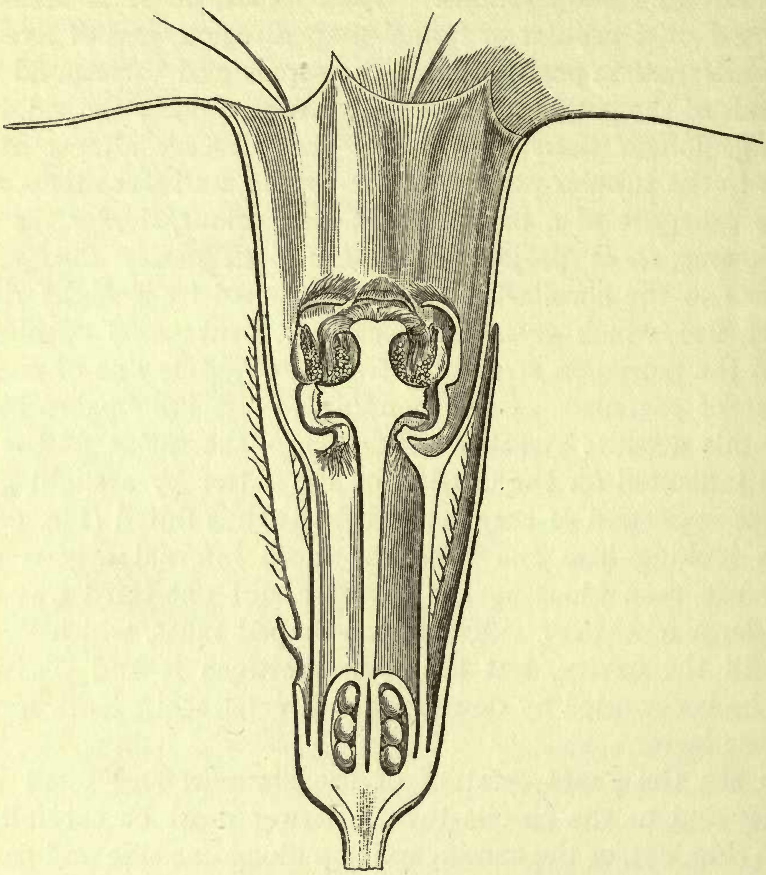


FIG. 68.—Flower of the Greater Periwinkle cut in half. (After Baillon.)

the green ovary; from this springs a cylindrical style which gradually widens till the level of the inwardly projecting filaments is reached. Above this the style suddenly widens out into a disc at the level of the concave portions of the filaments, which arch round it. The expanded disc is surmounted by a narrower portion. The summit bears a plume of white hairs, which slope downwards on all sides between the tip of the style and the upper

surface of the cylindrical expansion of the style. The sloping surface formed by these hairs lies immediately within the circle of anthers. The actual receptive surface or stigma is not at the tip of the style, but is the vertical edge or outer surface of the disc-like widening of the latter. The relative positions of the regions of the stamens and style are constant, and will be better understood from a study of the flower with the help of Fig. 68 than by any further description. The lower portions of the filaments bear downwardly directed hairs, and, as was seen on looking into the flower, the space between the stamens and the corolla-tube is filled up with similar hairs springing from the corolla. The latter hairs are omitted in Fig. 68.

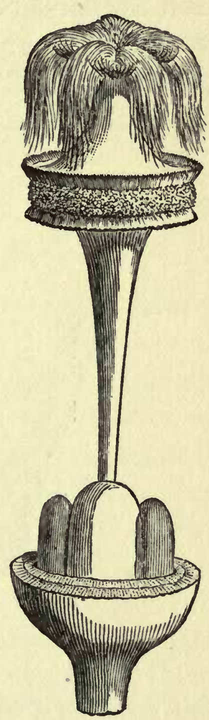


FIG. 69.—Pistil of the Greater Periwinkle. The nectaries are seen to either side of the ovary. (After Baillon.)

The ovary consists of two carpels, which are separate from one another in the lower region of the pistil but joined to form the style. Each carpel in the ovary encloses a cavity which has two rows of ovules springing from the infolded inner margin. Seen from the outside, the ovary has the appearance of a deeply two-lobed, flattened, green body. Alternating with the lobes are two yellowish green glands, not much behind the carpels in size. These are the nectaries, and the nectar formed by them accumulates around the ovary in the lower part of the corolla tube.

If this very complex inter-relation of the parts enclosed by the corolla is considered with regard to the action of the insects visiting the flower it will be found to be intelligible as a very beautiful adaptation for cross-pollination. The insects come in search of the honey, and only those with long tongues can reach this. Humble-bees and some smaller bees are the chief visitors to the Lesser Periwinkle, while only bees with still longer tongues and moths can obtain the honey from the larger flowers of *Vinca major*. The insects alight on the flat, target-like expansion of the corolla, and will pass their tongues down to the nectar. Owing

to the curving of the stamens and the attachment of their stalks to the corolla, the insect's tongue must be passed down one of the five intervals between the stamens. The hairy ridges on the upper part of the corolla-tube further direct the insect to the narrow passages, which lie opposite the middle lines of the petals.

As soon as the flower opens the whole mass of pollen from each anther-lobe is shed and deposited in a mass on the sloping crown of hairs at the summit of the style. The pollen thus lies in a chamber roofed in by the flat tips of the stamens. It does not get upon the stigmatic surface, which is enclosed in a lower chamber formed by the five curved filaments. The stigmatic surface is very sticky and viscid. If no insects visit the flower the pollen remains undisturbed, and the stigma is not pollinated.

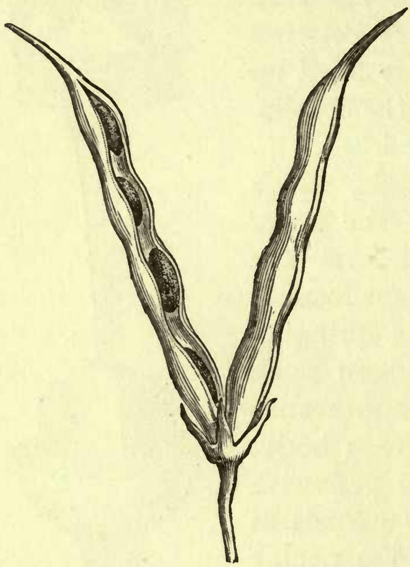


FIG. 70.—Fruit of the Greater Periwinkle opening to liberate the seeds. (After Baillon.)

When, however, the slender proboscis of an insect is passed down between two of the stamens to the nectar, it will evidently come in contact both with the pollen lying on the top of the pistil and with the stigmatic rim. The pollen is not as a rule moved downwards on the insertion of the insect's tongue, but when this is withdrawn the region which has rested against the stigma is sticky from the abundant stigmatic secretion, and a quantity of pollen adheres to the sticky surface and is carried away on the proboscis. This is not likely to be deposited on the stigma of the same flower, since the insect has exhausted its nectar and will pass to another flower. In this the pollen-covered region of the insect's tongue will rest against the stigma, which will thus be cross-pollinated receiving pollen from the first flower.

The whole construction of the flower becomes comprehensible when the way in which pollination is effected is understood.

The action of the insect can be imitated by passing a fine bristle down one of the openings between the stamens, and on then inserting the bristle into a second flower this will be pollinated and will develop a fruit.

In the wild state in this country many of the flowers do not form fruits, though these can be found on careful search. The corolla, with the stamens and the style, drops off, while the two halves of the ovary separate and increase in size. When ripe, these open along the line of union and liberate the seeds (Fig. 21). Many of the flowers drop off without forming fruits, even when pollination has taken place.

The White Dead-nettle (*Lamium album*, L.).

The White Dead-nettle grows in social groups, often on grassy banks or beneath hedges; and can be found in flower from about May until late in the year. It is a perennial plant, and, though the leafy shoots die down for a short time in the winter, can be found year after year on the same spot. Although the arrangement and shape of the leaves resemble the Stinging Nettle, the two plants are not related, and the hairs on the shoots of the Dead-nettle have not the special complicated structure of those of the Stinging Nettle, nor do they sting.

To understand the growth of the plant, the leafy shoots must not be merely picked off, but the underground parts bearing them must be carefully dug up (Fig. 71). The green, leafy shoots will be found to be the ends of longer or shorter underground branches. These are whitish, and have a four-sided stem with distinct internodes. At each node is a pair of small scale-leaves. The cross section of the stem is square, and the internodes are not hollow as they are in the aerial stems. Numerous roots spring from the nodes and extend into the soil, giving off lateral roots. In the axils of the whitish scale-leaves are buds. These grow out into branches, which may have a longer or shorter underground portion and then grow into an erect shoot. The crop of new shoots growing up in the spring comes from such buds.

The stem of the aerial shoots is also quadrangular, but it is only solid at the nodes. The internodes are hollow, and this

tubular construction, while quite rigid, economises the material needed in the growth of the shoot. Two leaves are borne at each node, and stand immediately opposite to one another. The pair of leaves alternates in position with the pairs immediately above or below. This arrangement avoids the shadowing of the leaves of one pair by those borne at the succeeding node. The stem is green or purplish in colour, and is sparsely covered with white hairs. Each foliage-leaf consists of a slightly widened leaf-base, a well-marked leaf-stalk, and a simple leaf-blade ; there are no stipules. The leaf-stalk is grooved above and rounded below, and its margins bear long soft hairs. The blade widens out suddenly at the upper end of the leaf-stalk, and just above this attains its greatest breadth, from which it gradually narrows to the tip. Its margin is cut into teeth, which point like the teeth of a saw to the tip. The blade is traversed by a midrib, and it, as well as the main branches which form a beautiful network, project on the paler lower surface.

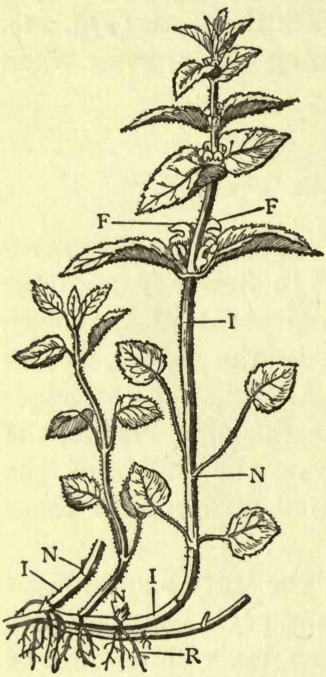


FIG. 71.—Plant of the White Dead-nettle. R, roots ; I, internode ; N, node ; F, flower. (After Farmer.)

While buds which may give rise to small lateral shoots are found in the axils of some of the lower leaves, all the upper pairs of leaves have clusters of flowers in their axils. The flowers are so closely crowded that they appear to completely surround the stem at the node. They are, however, in two groups in relation to the two leaves. The cluster of flowers lowest on the shoot begins to open first, and is succeeded by the group at the next node, and so on. The flowers of any one axillary group also do not open simultaneously. The first to open is the flower standing immediately over the leaf-base ; this is followed by one to either side, and these by buds standing laterally to them. All these flowers after the first one stand in the axils of minute, pointed

bracts, which can be easily made out, but the whole inflorescence is so condensed and shortened that it is difficult to follow the branching in detail.

The flower (Fig. 72) is an interesting one, and deserves careful and repeated study. All the flowers stand in a definite position with regard to the shoot, so that a front and back and two sides can be distinguished. Unlike such flowers as the Buttercup and Primrose, which are symmetrical about the central point, that of the Dead-nettle can only be divided into similar halves by one plane. This passes through the flower from front to back. Such a flower is described as irregular, in contrast to the regular flowers mentioned above, and it will be found that this feature leads to

FIG. 72.—White Dead-nettle. A, flower from the side; B, flower cut in half; C, lower part of a flower cut in half more highly magnified. (After Baillon.)

a greater precision in the relation between the parts of the flower and visiting insects than is usual in regular flowers.

The five sepals are united to form a tubular calyx, from the margin of which the pointed tips of the sepals project. One sepal stands in the middle line of the flower behind. The calyx is green with purplish markings, and the tubular part is ridged. The petals are also joined together to form the corolla, which is tubular below but divided into two well-marked lips at the upper part. The lower lip, which widens out and has an indentation in front, is composed of one petal. The sides of the entrance to the tube are bounded by pointed lobes, which mark the position of lateral petals; while the upper lip, though undivided, is made up of two petals. This can be shown by comparison with related plants,

but can also be inferred from the presence of a sepal in the middle line behind since the petals alternate with the sepals. The corolla is easily removed, and, looked at from the side, shows a narrow tubular portion at the base. Above this it widens out suddenly into a sort of pouch in front, and continues to widen slightly until it divides into the two lips described above. When split open, or in a flower cut in half, a number of white hairs will be found blocking the corolla tube just where the narrow part at the base ends (Fig. 23, c). The whole corolla is of a yellowish white tint.

There are four stamens, not five as might have been expected. The stamen which should stand in the middle line behind is absent. The stamens are joined on to the corolla, and their attachment will be seen on slitting up a corolla in the middle line behind and spreading it out. The two stamens, which are attached farther forward in the flower, have longer stalks than the other two, and their anthers stand in front of those of the other pair. All four anthers lie beneath the upper lip of the corolla, which protects them from wet, and they face downwards. The pollen does not drop out of the open anthers.

The style is also bent backwards, and lies between the stamens beneath the upper lip of the flower. It ends in a two-lobed stigma, one branch of which is directed forwards and the other backwards. The inner surface of these lobes is the receptive one for the pollen. Usually the style, being entangled among the stamens, is pulled off when the corolla is removed, but sometimes it can be left in position. It is then seen to spring from the centre of four green lobes, which are visible on looking into the cup-like calyx. These are the four lobes of the ovary, which is not, however, composed of four carpels but, as the two-lobed stigma indicates, of two. Each of these is subdivided into two chambers, and in each of the four cavities thus formed is a single ovule. If the calyx is carefully split open with the point of the knife, and peeled away from the ovary, two delicate whitish yellow scales will be seen lying against the front of the latter, and springing from beneath it. These are the nectaries, and the nectar accumulates in the narrow lower part of the corolla tube protected by the ring of hairs.

When the structure of the flower has been made out by dissecting several examples an intact flower should be considered in relation to the insects which visit the flowers in search of the nectar. This can only be reached by insects with a fairly long proboscis, and the flowers are in fact visited by humble-bees and other large bees and adapted for pollination by them. The way in which this comes about can be inferred by a study of the flower, but whenever possible growing plants in flower should be watched on fine days, and the insects which come to seek the honey noted and their behaviour observed.

The bee alights on the lower lip of the corolla, and thrusts its head as far down the wider portion as possible. Its proboscis thus reaches the nectar, and it remains sucking this. The body of the bee fills up the space between the under and upper lips, so that its back presses against the latter. The stigma and anthers are placed beneath this, the front lobe of the stigma projecting farther forward than the other parts. The bee will first come in contact with this, and pollen brought on its back from another flower may be deposited on the stigma. A further supply of pollen from the anthers, which have been seen to open downwards, will be deposited on the corresponding portion of the insect's body, and will be deposited on the stigma of the next flower visited. Since the stigma is receptive when the stamens are shedding their pollen, the flower may readily be self-pollinated by the insect. But since the flowers are largely visited, and insects pass rapidly from flower to flower in search of the honey, the chance of cross-pollination is very great. All the features in the construction of the flower are to be understood as rendering this probable.

After pollination the corolla falls off, carrying with it the stamens and the style, and the ovary enlarges and becomes the fruit. The lobes develop into four nutlets, each containing a single seed. When mature the nutlets split apart and are shed separately, but show no special arrangements to facilitate dispersal. Since each contains only one seed, there is no need for the nutlet to open, and its wall protects the seed until this germinates and gives rise to a new plant.

THE DANDELION (*Taraxacum officinale*, Web.).

The Dandelion can be found in flower from early spring to late in the autumn. It grows in grassy ground and in waste places, its excellent method of fruit dispersal enabling it to become established in every suitable spot, where, being a perennial, it persists for years if undisturbed. In studying this plant it is well to bear in mind that we are dealing with a thoroughly successful plant, and to try to trace the reasons for this success.

A well grown plant in flower should be dug up. It needs care to obtain a complete specimen, for the root extends to a considerable depth, and is easily broken across in removing the plant. This consists (Plate) of a short, brown, tap-root from which finer lateral branches extend into the surrounding soil. At the upper end of the root we pass to the short, thick stem, which bears a rosette of green foliage leaves. Sometimes the shoot has branched, and several rosettes of leaves are related to the one root. The shoots do not rise above the level of the soil, being pulled down against this by the contraction of the main root. The wrinkling of the surface of the upper part of the root is an indication of this contraction having taken place. The inflorescences, which are commonly but inaccurately known as the "flowers" of the Dandelion, spring from the axils of the leaves.

The stem is only indistinctly marked by the scars of the foliage-leaves of former years. The present leaves arise close together from a short region of the stem, and spread out on all sides. Sometimes they are more or less pressed against the surface of the ground. The summit of the shoot is a bud composed of immature leaves. The foliage leaves consist of an expanded whitish base, narrowing into a short leaf-stalk, which passes as gradually into the leaf-blade. This has a well-marked midrib, from which the thin flat blade extends on either side. Near the tip the margin is entire, but lower down it is cut into lobes by indentations which extend almost to the midrib. The lobes are pointed, their points being directed backwards towards the base of the leaf. The sloping margin of each tooth is cut into smaller pointed projections.

The stalked heads that are usually known as the "flowers" of the Dandelion are really the inflorescences, each of which bears a large number of small flowers. Each inflorescence or flower-head stands in the axil of one of the leaves of the rosette. Since the main shoot does not grow into an inflorescence, it continues to produce new rosettes of foliage-leaves year after year as the older leaves decay.

The flower-head is borne on a cylindrical greenish stalk, which is at first short and only reaches its full length shortly before the flowers are ready to open. When the stalk is short it will be found to be covered with long cottony hairs, which doubtless assist in protecting it. The remains of these can be seen at intervals on the fully grown stalk, being most numerous just below the head where growth has been less rapid. The flower-head is surrounded by a large number of narrow green leaves or bracts, which at first fit closely together and completely enclose the little flower buds within. When the head opens the outer bracts bend back, but the inner longer ones stand up around the flowers. The relative positions of the bracts and florets, as the little flowers are called, will be best seen on splitting a flower-head in half. The hollow stalk of the inflorescence will be found to widen out into a hollow expansion which is slightly concave on the upper surface. The bracts are borne around the edge of this, while the little flowers are closely crowded together in the centre.

The flowers can be readily pulled off singly, and their structure should be carefully made out with the assistance of the pocket-lens. This will be most easily done if fresh inflorescences with expanded florets are taken on a fine sunny day. All the florets in a flower-head are alike.

At the base of the floret is an elongated, oval, whitish swelling. This is the ovary, which is here inferior, all the other parts of the flower springing from above it. Immediately above the ovary we come to a very short greenish stalk, narrower than the ovary itself, and at the upper limit of this the structure which takes the place of the calyx is borne. This is a circle of long, fine, white hairs, which stand up around the lower part of the corolla. The use of this peculiarly developed calyx will be seen when we

consider the fruit of the Dandelion. It may be noted, however, that, since all the little flowers are protected by the bracts around the inflorescence, there is no need for the calyx of each flower protecting the parts within.

The corolla is composed of five petals united together to form a tube, which continues on the side away from the centre of the inflorescence as a long, flat, strap-shaped extension (Fig. 73). If the edge of this is looked at with a lens it will be found to be divided into five minute teeth. This is the only indication in the mature flower of the five petals, which are joined together to form the corolla.

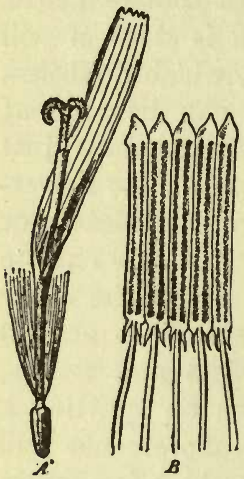


FIG. 73.—Dandelion. A, single floret; B, the five stamens showing the free filaments and the anthers united edge to edge to form a tube, which is here shown slit open. (After Warming.)

Considerable care and patience will be needed to make out the other parts of the flower. If a well opened floret be chosen from near the outside of a fully expanded head and examined with the lens, there will be seen projecting from the tube of the corolla a yellow column, and from the top of this a more slender stalk divided above into two lobes (Fig. 73, A). The yellow column is composed of the anthers of the five stamens. These are joined edge to edge and form a tube. If, however, the lower parts of the stamens are looked for, the five separate stalks will be seen. These bend from the bases of their respective anthers to the inner surface of the tubular corolla to which they are attached. The way in which the stamens are joined will be understood from Fig. 73, B. The thin structure projecting from the anther tube is the style, dividing at the top into the two lobes of the stigma. With a little care the tube formed by the anthers can be slit along one side with the tip of a sharp knife, and the style pulled away and traced down into the tube, where it springs from the summit of the inferior ovary. The pistil is really composed of two carpels, but the only indication of this is afforded by the two lobes of the stigma, which correspond to their free tips. Within

the ovary, if it is carefully opened, a single ovule, attached to the base of the little cavity, will be found.

The description above refers to a fully mature floret. In order to understand the mode of pollination it is necessary to follow the changes in the flower from its opening until it is fully grown. If an inflorescence be selected in which some of the florets in the centre are still unopened, the florets immediately outside these will be a little older and have just opened, while the outermost florets will be the oldest. In the florets which have newly opened the yellow anther tube will be visible, but no trace of the style or stigma. The stamens have shed their pollen into the hollow cylinder formed by the anthers. As the style, ending in the stigma, the two lobes of which have not yet separated, grows in length it pushes its way up this cylinder and sweeps out the pollen; this accumulates as a little yellow mass at the summit of the tube. When the stigma has reached the top of the anther tube the pollen is all swept out, and as the growth of the style continues the two lobes of the stigma separate and expose the receptive inner surface, which has till now been safe from contact with the pollen.

Flowers in the first or pollen-shedding stage, and the second or pollen-receiving stage, occur in the same inflorescence. The whole expanse of one to two hundred florets contained in the inflorescence makes a conspicuous and brightly coloured object in the sunshine. It is visited by many insects, by small flies which come to eat the pollen, and by longer tongued insects in search of the nectar secreted at the bottom of the corolla tube. The insects coming in contact with florets in the first stage will be dusted with pollen, and in passing from flower to flower may deposit this on the open stigmas of older flowers in the same or in another inflorescence.

Should the florets not be cross-pollinated in this way the lobes of the stigma, as they continue to curve back, will bring the receptive surface in contact with some of the pollen still adhering to the hairy outer surface of the style, and so the floret will in any case be self-pollinated.

There are other complications in the reproduction of the Dandelion into which we cannot enter here. A careful study of

the construction of its flowers and of the way in which they are suited to pollination by insects will prepare the student to understand the pollination arrangements in other members of the great family of plants to which the Dandelion belongs.

Practically every floret produces a fruit. The heads bearing the ripe fruits are familiar to all children as "clocks." After flowering the head closes up while the fruits are developing, but when the latter are ripe the bracts are bent back and the fruits stand on the convex upper end of the inflorescence. Each fruit has come from a single little flower. The corolla and stamens of this have withered and fallen off, and the ovary has enlarged into the fruit itself. The short stem-like region, which intervened between the ovary and the hairy pappus, has lengthened and carried the latter up on a long stalk. The hairs of the pappus are bent back, and stand at right angles to this stalk, forming a parachute-like expansion. The fruits are very easily detached from the head, and are carried by the wind with the help of the expanded pappus. When they settle down in a crevice of the soil they will tend to remain owing to the presence of small upwardly directed teeth on the surface of the upper part of the ovary.

The success of the Dandelion and of many of its relations, such as the Groundsel and Thistles, depends largely on the certainty of each flower producing a fruit, and on the excellent adaptation these show for wind dispersal.

The Tulip.

The many cultivated forms of the Tulip are for the most part varieties of a wild species, *Tulipa gesneriana,* which was introduced from the Levant. In Britain one species with yellow flowers, *Tulipa sylvestris,* is found growing wild. Any of the single varieties of cultivated Tulips will serve for study with the help of the following description. The examination of the plant may perhaps be best commenced at its flowering season in the spring, when it will have the appearance represented in the figure (Frontispiece), but its life-history should be carefully followed through the year. A plant in flower will be found to consist of

the bulb, from which roots extend down into the soil, while the unbranched stem grows upwards, bears a few foliage-leaves, and ends in the single large flower.

Such a plant has been grown from a bulb, which is usually planted in the autumn to flower in the following spring. We may commence by considering the construction of such a bulb, and follow its development into the full-grown plant. A bulb is a specially modified shoot, and consists of a small stem bearing a number of leaves. This is best seen if a bulb is split in half, when the small flattened stem will be found to bear a series of closely crowded, white, fleshy scales. These overlap one another and fit closely together. The outermost leaf is developed as a brown protective scale, completely enveloping the rest of the bulb. The inner surface of this thin scale is clothed with fine hairs, all pointing towards the tip of the bulb. The thick, white scale-leaves within contain a store of reserve food material, which was manufactured by the leaves of the parent plant in the preceding season. In the centre of the bulb is a yellowish shoot, a continuation of the stem which bears the scales of the bulb. This shoot already consists of the foliage-leaves which will expand next season. These closely surround the single flower, with which the stem ends. In the flower all the parts are already developed and, like the leaves, only need to grow to their full size.

When placed in the soil the short stem produces numerous roots, which spring from the region between the protecting scale and the lowest storage scale and so form a fringe around the base of the bulb. The shoot in the centre of the bulb commences to grow at the expense of the material stored up in the scales of the bulb, and appears above ground as a cylindrical stem bearing three or four foliage-leaves. Each of these consists of a broad sheathing base, which extends completely round the stem ; this passes without any leaf-stalk into the leaf-blade, which has a simple oval outline. This leaf-blade is rather thick and fleshy, and the veins in it can be seen to run parallel to one another. No buds are evident in the axils of the foliage-leaves, and the shoot remains unbranched. A longer or shorter region of bare stem, the flower-stalk, separates the highest foliage-leaf from the flower.

When the bulb of a plant from which the shoot has grown up is compared with the bulb at the time of planting, great changes are apparent. It is rooted in the soil and partly by the escape of the roots, partly by the increase in size of the enclosed parts, the brown protective scale is more or less ruptured. The storage scales within, which were plump and white, are now shrivelled and drying up. The food material stored in them has been removed and utilised in the growth of the shoot and flower. The use of these storage scales is over, and they will now gradually decay.

The development of the bulb or bulbs, which will remain in the ground after the rest of the plant has decayed, is already far advanced. These new bulbs arise from buds situated in the axils of the inner storage scales of the parent bulb. The bud enlarges and develops into a bulb like that with which we started. As the new bulbs grow they force apart and rupture the withered scales of the old bulb. On dissecting one of the developing bulbs the protective outer scale, which is still soft, and the series of storage scales can be distinguished. In some cases the protective scale will be found to bear a small green leaf-blade, and this shows that the overlapping bulb-scales correspond to the transformed bases of leaves which completely surround the stem. The food material, which is being stored in the growing bulb or bulbs, is formed by the activity of the green foliage-leaves exposed to the light, and is conveyed downwards through the stem into the bulb-scales, where it accumulates as starch. Since the growth of the shoot took place at the expense of the material stored in the old bulb, practically the whole of the substance manufactured by the foliage can be saved and stored up in new bulbs. The Tulip, like many plants which flower early in the season, depends for its growth on material manufactured in the preceding season.

In some cases only a single new bulb is formed, but usually, under favourable conditions of nourishment, two or three bulbs of considerable size develop, and sometimes other smaller ones. When the old bulb decays these become isolated from one another in the soil, and so form independent plants in the next season. The formation of the new bulbs thus serves to increase the number of individuals, and is a most efficient means of vegetative repro-

duction. In multiplying the number of individuals of any particular variety of Tulip, horticulturists rely entirely on this vegetative mode of reproduction. Each new individual produced in this way represents a detached lateral bud of the parent.

The flower, with all its parts developed, has been seen to be already present in the bulb at the time of planting. The outermost leaves of the flower are at first closely folded over the more delicate inner structures, and are firm and green. As the flower becomes ready to open the outer leaves become brightly coloured, and there is often little difference to be made out between the two series of floral leaves, both being delicate in texture and coloured. Each flower has thus two whorls of three perianth leaves, between which no distinction of calyx and corolla can be made. The leaves of the inner whorl alternate with the three outer perianth leaves. The other parts of the flower follow in regularly alternating whorls of three. There are two whorls of stamens and three carpels united together to form the pistil. The latter stands in the centre of the flower and occupies the summit of the floral receptacle.

The perianth leaves are brightly coloured, red and yellow in various shades and combinations being the prevailing colours. White varieties are also common. The stamens have short, thick stalks and large erect anthers, which shed their pollen inwards towards the centre of the flower. The pollen is somewhat sticky, and does not fall out of the open anthers. Each stamen is joined to the base of the perianth segment opposite which it stands, and when this is removed the stamen comes also.

The pistil is a green three-sided column surmounted by three diverging, rough, yellowish surfaces. The lower portion is the ovary, the three-lobed summit the stigma. The number of lobes of the latter indicates that the pistil is composed of three carpels united together, and further evidence of this is obtained by cutting the ovary across. On examining the cut surface with a lens three cavities will be seen, separated by partitions that run inwards from the flat sides. The three projecting angles of the ovary correspond to the midribs of the three carpels. The ovules are borne on the margins of the carpels, which meet in the centre. The two rows of ovules present in each

chamber appear to be borne on a central column traversing the pistil.

No nectar is secreted in the flower of the Tulip, which is, however, conspicuous, and is visited by insects. These feed on the pollen, and in doing so may carry some of it from the stamens of one flower to the stigma of another, and so effect cross-pollination. After being pollinated the pistil develops into a capsule containing numerous seeds, but in cultivation the Tulip is rarely reproduced in this way except for the production of new varieties.

The germination of the seeds is, however, very interesting. This takes place at no great distance below the surface of the soil, and not at the depth usually occupied by the bulb. The necessary depth is reached by the formation of what are known as "droppers." The seedling sends a root into the soil, and the cotyledon appears above ground, its tip remaining for a time in the seed-coat to absorb the nourishment stored there. The growing point of the shoot becomes carried down in a tubular prolongation of the sheathing base of the cotyledon. By means of this "dropper" the bud, which forms the small bulb of the plant in its second year, is placed deeper than the original seedling. This may happen for several years. Ultimately the bulb becomes strong enough to produce a flower. The first flowers produced are as a rule self-coloured, and after two or three years or longer "break" into coloured blossoms. It is not possible to enter farther into the production of new varieties of the Tulip, which once established usually come true when reproduced vegetatively. Enough has been said to indicate the interest attaching to the whole life-history as well as to the regular annual development from the bulb, which can be more easily followed.

The Field Woodrush (*Luzula campestris*, Willd.).

More or less extensive patches of this little plant may be found in almost any piece of grassy ground. Though the individual plants are inconspicuous, the colonies formed by them can be readily distinguished when in flower even from a distance. The plant is a perennial, and not only appears year after year in

the same spot, but spreads on all sides in a most successful fashion. In spite of its grass-like appearance the Woodrush is not a true Grass, and will be found to resemble in the construction of the flower such plants as the Tulip and Lily rather than the Grasses.

The firm underground stem, from which the leafy shoots spring, is covered with the brown and withered bases of the leaves of former seasons. Fine roots also spring from it, and grow down into the soil. When the end of a shoot grows on into an inflorescence, the further growth of the plant continues from lateral buds. The leaves at the base of such a shoot are small and scale-like. Above them come the long, narrow, grass-like foliage-leaves. These have a long sheathing base which surrounds the stem, and a narrow flat leaf-blade with parallel veins. Fine silky hairs are conspicuous at the margin of the blade, and where the latter joins the sheath. The stalk of the inflorescence has elongated internodes, and the leaves borne at the nodes are smaller than the foliage-leaves. Still smaller leaves or bracts are present below the branches of the inflorescence, while the closely crowded flowers stand in the axils of scale-leaves.

The appearance of the inflorescence differs according to the stage of opening which the flowers composing it have reached. In the first stage the flowers are still closed as in the bud, the brown perianth leaves not having expanded. From the tip of the closed perianth of each flower the style projects just far enough to allow the three whitish stigmas to expand. These are of relatively large size, and when looked at with a lens show a rough or feathery surface. In flowers at this stage the stigma is ready to receive pollen, which evidently cannot come from the same flower, since this has not opened to expose the stamens. It is even unlikely that the pollen will come from a flower on the same inflorescence, since all the flowers are often at the same stage. If the flower be watched, or if a series of inflorescences in successively later stages be collected and compared, the stigmas will be found to wither and turn brown before the perianth expands. When this takes place the stamens are ready to open, and the flower is in the second stage.

The structure of the flower will be most readily made out from

such a fully opened specimen (Fig. 74). The perianth will be found to consist of six small brown pointed leaves, which form two series of three, the inner whorl alternating with the outer whorl. The perianth leaves are very unlike the delicate coloured petals of most other flowers. They are dry and scale-like, with a thicker brown midrib and a thin greenish or brown margin. While they protect the parts within in the bud, they do not, even when fully expanded, render the flower conspicuous, as do the petals of many equally small flowers.

Within the perianth come six stamens, also in two whorls of three. Each stamen has a short stalk, which continues into a relatively large anther. In the unopened anthers the four pollen-sacs can be distinguished as four ridges, but on the opening of the anther the loose powdery pollen is exposed. In the centre of the flower is the pistil, consisting of the small green triangular ovary, a slender style, and the three long branches of the stigma. The pistil is composed of three carpels, as is indicated by the number of stigmatic lobes, which are by now withered and no longer capable of receiving pollen. The ovary contains three ovules in its single cavity, and at this stage has commenced to develop into the fruit.

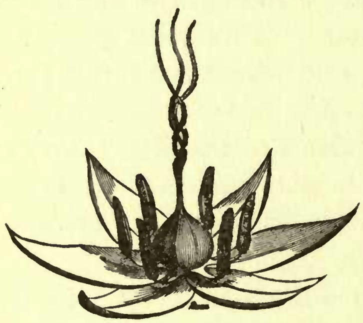


FIG. 74.—Flower of the Field Wood-rush fully opened. (After Baillon.)

The features of this flower can only be understood in the light of the method of pollination. The flowers are inconspicuous and secrete no nectar. They thus offer no inducements to insects to visit them. They are, in fact, pollinated by the help of the wind, and not by insects, and all the characters in which they differ from brightly coloured and conspicuous flowers fit them for this. The pollen, in contrast to that of most of the other plants described here, is loose and powdery, and the stamens are freely exposed in the open flower. If on a fine warm day one of the inflorescences be gently tapped or shaken, a cloud of dusty pollen will be found to escape into the air. Evidently thousands of pollen grains will

be floating in the air around a colony of the plants. Some of these may come in contact with the stigmas of other flowers, and we can now appreciate the use of the large rough stigmas, which are well fitted to catch and retain the pollen grains borne against them.

The likelihood of pollination being effected in this way is increased by the social mode of growth of the Woodrush, which leads to many inflorescences being present within a limited radius. Some of these inflorescences will bear flowers in the earlier, some in the later stage. This is important, since, as has been seen, the stigma alone is exposed in the earlier stage, and withers before the stamens of the same flower shed their pollen. Self-pollination is thus impossible, and pollen must always be brought from a distinct flower in the second stage, and probably from another plant.

The Woodrush is an instructive example of a wind-pollinated flower, and its features should be contrasted with those of the insect-pollinated Tulip, in which the general plan of construction of the flower is almost the same. The Woodrush is peculiar both in the absence of conspicuousness and other attractions, which are present in order to attract insect visitors in other flowers, and in such features as the large stigma and the powdery pollen which directly assist in wind-pollination. These general characters are found in the flowers of many other wind-pollinated plants, and associated with them we often find arrangements to prevent self-pollination. This is sometimes effected by the stamens being in one kind of flower and the pistil in another, but in the Woodrush the flower contains both stamens and pistil. We have seen, however, that the sharply marked stages of flowering result in each flower being at first in a pollen-receiving and later in a pollen-shedding condition. It is instructive to compare, in this respect, the Woodrush with the Ribwort Plantain, which is described below.

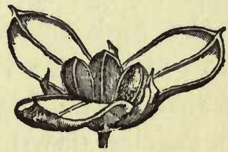


FIG. 75.—Fruit of the Field Woodrush opening to liberate the seeds.

That the mode of pollination is thoroughly effective is shown by the way in which practically every flower gives rise to a fruit. This is formed from the ovary, and when ripe its dry wall splits into three valves which bend apart and allow the three, relatively large, seeds to escape (Fig. 75).

THE DAFFODIL (*Narcissus pseudo-narcissus*, L.).

The Daffodil or Lent Lily is found growing wild in many parts of England, and is cultivated everywhere for the sake of its flowers. Whether it is a truly native plant or one of those we owe to the Roman occupation of Britain is uncertain. In any case the plant grows successfully in pastures, copses, and by the banks of streams, sending up its long green leaves and single flower each spring, while the bulb is hidden and protected beneath the ground. The appearance of the plant is well shown in the photographs in the accompanying Plate.

The general course of the annual history of the Daffodil resembles that of the Tulip and many other bulbous plants. The bulb, hidden in the ground, already contains in the autumn the leaves and flower, which will appear and grow to their full size in the spring. The foliage-leaves remain exposed to the light and air throughout the early summer, after the flower has given rise to a fruit or has withered, and then in turn die down. The food material manufactured by the foliage-leaves is carried down and stored in their basal parts, and in the bases of some outer leaves which do not bear leaf-blades. These leaf-bases form the bulb of the next season. It is at the expense of the material stored in this bulb that the growth of the shoot and flower of the following spring will take place.

The bulb of the Daffodil is best examined in a specimen in which the shoot is commencing to grow in the winter or in a flowering specimen in spring. A number of long, unbranched, white roots will be found, growing down from the base of the stem. The construction of the bulb will be best appreciated if two specimens are taken, one of which is split in half lengthways while the other is cut across with a sharp knife. On the outside are some thin withered brownish scales; these are the remains of the leaf-bases of the season before last. Within these come the sheathing white bases of the leaves of last season; these constitute the bulb-scales. They are arranged in two rows, each leaf standing a little higher on the short stem, and opposite to the preceding one. The outermost three of these scales were the bases of scale-leaves, while the inner two or three belonged

to last year's green foliage-leaves. In the axils of one or two of the outer scales buds may be developing, while the base of last year's flower stalk, which, like the scales, has served for storage of food material, stands in the axil of the uppermost scale. Within these scales, which constitute the bulb formed last year, the shoot continues for the present season. The short region of stem bears similarly three scale-leaves and a few foliage-leaves. In the axil of the uppermost of these is the single flower, while the tip of the shoot is commencing to grow into the shoot of next year. The arrangement of the leaves will be understood from the diagram in Fig. 76.

The bulb of the Narcissus thus differs from that of the Tulip in that the flower is lateral and does not terminate the shoot. This is therefore capable of giving rise to the shoot of the next season. Another difference lies in the fact that the bulb-scales are here the thickened bases of the leaves of the preceding season. While the main shoot continues, if undisturbed, to grow on year after year, the lateral shoots developed from the bulbs referred to above give rise to small bulbs. As these become free from the main shoot by the decay of its older scales they serve as a means of multiplying the plant vegetatively. Thus from a single bulb a small colony of plants may be derived by vegetative reproduction in the course of a few years.

The foliage-leaves have, above the sheathing and thickened leaf-base, a long narrow leaf-blade of a bluish-green tint. The midrib is convex below, while the upper surface is concave. The veins, as in the Tulip, run parallel in the blade, and do not form a network.

The flower, the position of which in the axil of the uppermost foliage-leaf has already been noted, is borne on a long, ribbed, green stalk. A short distance beneath the flower itself is a brownish membranous sheath, which serves to enclose and protect the flower when in bud, and later remains around the base of the flower. This sheath is made up of two bracts, borne on the stalk, joined together. Above the sheath is a very short region of flower-stalk continuing into the flower. This region of the flower-stalk is straight in the bud and until shortly before the flower opens. It then undergoes a bend or curvature, which

is always so directed that the flower faces the strongest source of light. In the Daffodil there is always a single flower, but in related species of Narcissus additional flowers develop in the axils of the bracts which form the sheath.

At the base of the flower is the inferior ovary, which appears

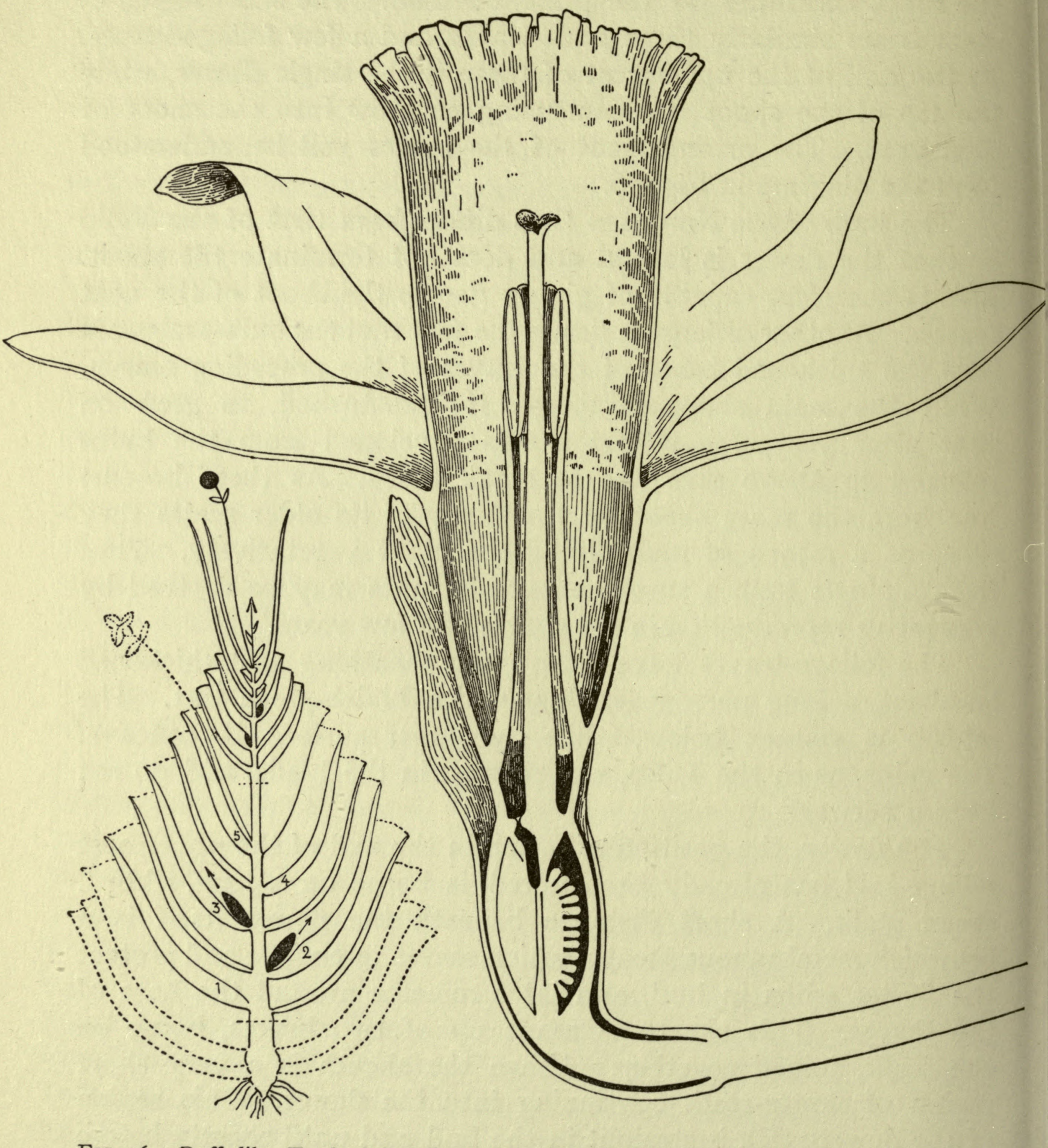


FIG. 76.—Daffodil. To the left a diagram of the arrangement of the leaves on the stem of a flowering specimen. To the right a flower cut in half. (After Church.)

as an enlargement of the flower stalk. It is somewhat triangular when cut across, and shows three cavities. In each cavity, springing from the inner angle, are two rows of ovules. All the other parts of the flower appear to spring from the summit of the inferior ovary. The perianth is composed of two whorls of three leaves each; there are two whorls of three stamens, and in the centre is the style, ending in a three-lobed stigma, which indicates that the pistil is composed of three carpels. The modifications due to the unequal growth and the union of the parts of the flower will be best understood from Fig. 76, which represents a flower cut in half.

In the centre of the flower is the cylindrical style, which springs from the summit of the ovary and is formed of the upper portions of the three united carpels. It bears the three lobes of the stigma at its upper end. The other parts of the flower form by their union a tubular or bell-shaped structure of rather complex construction. Above the ovary comes a short, tubular region. Just where this widens out into the next region, which extends to the place of divergence of the free parts of the perianth leaves, the six stamens are borne on the inner surface of the tube. Three of the stamens are inserted at a lower level than the other three. The stamens have short yellow stalks, and the large anthers stand close around the style. The second or middle region of the perianth tube is wider than the lowest region. At its upper limit the two series of free pointed perianth segments diverge almost at right angles to the tube. The outer three segments are broader than the inner three.

Above the divergence of the perianth segments the tube of the flower is continued as a cylindrical tube of a deeper yellow colour. The inner surface of this is wrinkled, and the edge is slightly frilled. This structure, which is peculiar to the Daffodil and its near relations, is called the *corona*. In the Daffodil itself it makes up the largest part of the tube. The corona is a new formation in the flower and appears late in its development, after all the other parts have been formed. It extends forward beyond the style and stamens, which are completely protected by it.

As compared with the Tulip or the Woodrush, we find the

flower of the Daffodil to have the same number of parts but to have an inferior ovary (cf. p. 106), and to have the other parts peculiarly developed and united. The use of the arrangement of the parts will be appreciated when the method of pollination is considered. This is effected by insects, which visit the flower for pollen or nectar. The nectar is secreted by three slit-like glands which extend for some distance into the three partitions of the ovary, and it accumulates in the basal region of the tube. It is thus a long way from the opening of the corona. In the middle of this the stigma stands ready to receive pollen, while the stamens around the style a little farther back have opened and are shedding their sticky yellow pollen. An insect such as the humble-bee coming in search of nectar creeps into the tube of the corona, rubbing its back against the stigma and then against the stamens. It will thus be able to reach the nectar. On going to another flower the pollen on its back will be brought in contact with the stigma.

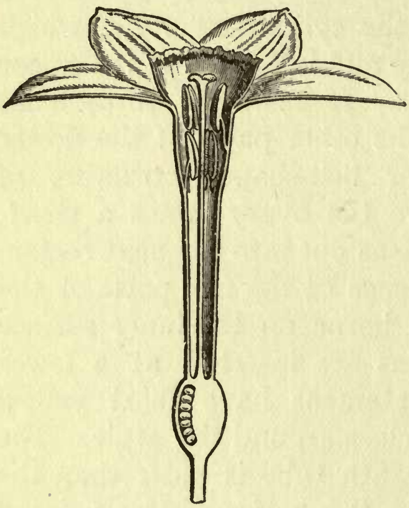


FIG. 77.—Flower of Pheasant's Eye Narcissus cut in half. (After Baillon.)

It is interesting to compare the flower of the Pheasant's Eye Narcissus (*Narcissus poeticus*) with that of the Daffodil as regards its construction and mode of pollination. The parts of the flower (Fig. 77) are as in the Daffodil, but the lowest region of the tube is much longer and narrower, while the corona is short and wide. The margin of the corona is reddish, while the perianth segments diverge at right angles to the tube. The flower has thus the appearance of a white target with a coloured centre. It is probably pollinated by moths, and not by bees creeping into the tube. These will be attracted as they fly in the dusk, and with their long tongues will be able to reach the nectar. In doing this they may convey pollen from the stamens of one flower to the stigma of the next. Self-pollination may,

Photo by Henry Irving, Horley

DAFFODIL (*Narcissus Pseudo-Narcissus*, L.)

however, be effected here even more readily than in the case of the Daffodil. The interest of the comparison of the two flowers lies in the fact that with very similar structure one is adapted to pollination by moths, and the other to pollination by large-bodied bees. Their study from this point of view is most instructive.

When a flower is fertilised the corolla withers and falls off, leaving the ovary, which enlarges and becomes the fruit. This is a dry capsule with three chambers, in each of which are two rows of smooth, black seeds. When ripe the fruit opens by splitting into three valves, with the seeds attached to their inner faces. The seeds fall off, but show no special arrangements for conveyance to a distance.

The Daffodil is well suited for thorough study, since it can readily be grown from the bulbs either in bowls or pots or in the garden, and the whole course of its annual history followed. One plant thoroughly studied in this way will be found of more value in awakening an interest in nature knowledge than a number hastily looked at.

The Blue Garden Crocus (*Crocus vernus*, All.).

The structure of the Crocus may be studied either in the Blue Garden Crocus (*Crocus vernus*) or the Yellow Garden Crocus (*C. aureus*), both of which are grown in every garden for the sake of their flowers. These appear in February and March. If plants of the Saffron Crocus (*C. sativus*) are cultivated in the neighbourhood its flowers may be studied in the autumn months. This plant is cultivated for the sake of saffron, which is obtained from the lobes of the stigmas, and was formerly grown on a large scale at Saffron Walden. The mode of growth of the Crocus is shown by all these plants, which differ in such details as number of leaves, colour of flowers, etc., but are constructed on the same plan. The description will be based especially upon the Blue Garden Crocus, which is grown in many varieties, some of which have the perianth violet-blue with deeper veins, others have only the veins coloured, while other varieties are white.

The underground part of the Crocus, which is situated some

four or five inches below the level of the soil, might at first sight be mistaken for a bulb. It is really, as is best seen on splitting it lengthways in half (Figs. 78, 79), a flat cake-like stem, bearing the remains of a number of thin brown scale-leaves. The food material is here stored in the stem, not in the thickened scale-leaves as in a bulb. The swollen underground stem is called a *corm*. The summit of the corm bears one or several buds, which stand in the axils of leaves borne upon it. Each of these buds grows into a flowering shoot, the growth taking place in the autumn and being completed in the spring, when the leaves and flower appear above ground.

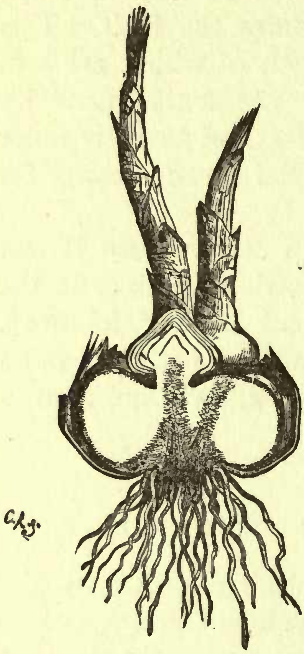


FIG. 78.—Yellow Garden Crocus. Corm, with the flowering shoots beginning to grow, cut in half. (After Baillon.)

The plant is fastened in the soil by numerous unbranched roots, which spring from the base of the corm, and serve to obtain the water and food salts required for growth. The material for the growth of the shoot and flower is obtained from that stored up in the corm, which has served its use as soon as the flowering is over and decays later in the year. A new corm is formed by the enlargement of the base of the flowering shoot, and this gets stored with the material manufactured by the foliage-leaves, and remains to carry on the growth of the plant next season.

When more than one shoot is present as many new corms will form (Fig. 78), and then on the decay of the old corm will become isolated from one another. In this way the plant is multiplied vegetatively, and does not merely persist year after year.

The shoot of the Crocus consists of a short stem bearing a number of closely crowded, thin, scale-leaves which enclose the parts within. These scales persist on the base of the stem when it enlarges to form the new corm. Above them come three to

five long, narrow foliage-leaves. These are dark green with a whitish stripe along the midrib. Above the foliage-leaves the shoot continues as a long slender flower stalk. This bears two scale-like sheaths, one near the base and the other at the upper end just beneath the ovary of the flower. This long internode of the flower-stalk carries the base of the flower nearer to the surface of the soil, but it is still situated some distance below the level of the latter. Usually the shoot only bears the single flower, but sometimes a second flower is produced in the axil of the scale at the base of the flower-stalk of the first flower.

The general relations of the parts of a plant in flower are shown in Fig. 79, which represents a plant of the Saffron Crocus cut accurately in half. The old corm rooted in the soil, the new corm in process of formation, the scale-leaves and the foliage-leaves are all seen. The long flower stalk is also clearly visible within the leaves of the shoot.

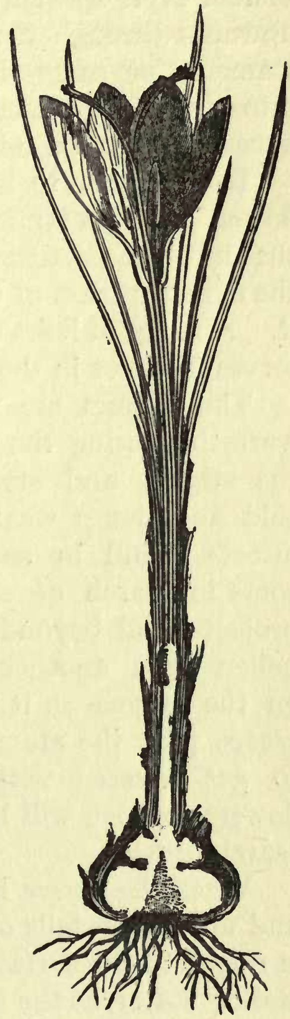


FIG. 79.—Plant of the Saffron Crocus in flower cut through longitudinally. (After Baillon.)

The flower is also shown cut in half in this figure. The ovary is inferior, and comes at the end of the flower stalk. It consists of three chambers, in each of which are two rows of ovules. Above the ovary comes a long slender tubular region. This extends to well above the level of the soil, and must not be mistaken for the flower-stalk. This tube widens out above, and divides into the six large coloured leaves of the perianth. These are in two whorls of three, an outer and an inner, and form the expanded, bell-shaped, upper region of the flower.

Just where the narrow tube widens into this region three

stamens are attached to it opposite to the three outer perianth leaves. These have short, rather stout stalks, and large anthers, which open outwards to shed the abundant yellow pollen. The slender style springs from the summit of the ovary, and extends upwards through the narrow part of the tube and between the stamens for some distance above the latter. It then divides into the three orange-coloured stigmas, each of which is rolled inwards to form a tube, while the edge is fringed.

It is further to be noted, in considering the structure of this flower, that nectar is secreted by three glands which extend as slits into the partitions of the ovary. The nectar accumulates in the narrow region of the tube, which is usually completely filled by it. A fringe of hairs at the level of the attachment of the stamens serves to cover in the nectar.

The flowers are very sensitive to changes of temperature, warmth causing the perianth leaves to bend apart and disclose the stigma and stamens, while the flower remains closed in cold and damp weather. They are visited by numbers of the insects found in early spring, especially by bees which may come in search of either nectar or pollen. Since the stigma projects well beyond the anthers, an insect already dusted with pollen from another flower will be likely to rub some of this on the stigma as it enters. Whether it feeds on the pollen or creeps past the stamens to get at the nectar, the insect is sure to get covered with pollen. The warmth which causes the flowers to open will be likely to induce insects to visit flowers in search of food.

When the flower is fertilised the perianth droops and withers and ultimately falls off. The ovary develops into the fruit, which is raised to the surface of the soil by further growth of the flower-stalk. Later, as the fruit ripens it is raised still higher, quite clear of the soil. The fruit ripens about June and is a somewhat three-angled capsule, which opens by splitting into three valves to liberate the numerous rather large seeds.

The foliage dies down shortly after this, and the later stages of the development of the new corm, and the preparation of the shoots for next season, are carried out below the surface of the soil, all trace of the plant above ground having disappeared. It will be

clear to the reader that the proper study of this plant requires the cultivation of specimens throughout the year, and their examination at various seasons. If this is done systematically, and records and drawings kept, the description given above, which only deals with the main points, may be greatly amplified, and material for an interesting course of Nature Study lessons accumulated.

CHAPTER VII

Early Summer Flowers

The Wild Strawberry—The Bird's-Foot Trefoil—The Daisy and the Feverfew—The Perennial Rye-Grass—The Garden Sage—The Cuckoo Flower and the Red Campion—The White Meadow Saxifrage and the London Pride—Herb-Robert—The Spotted Orchis—The Greater Plantain and the Ribwort Plantain—The Charlock—The Shepherd's Purse—The Common Avens——The Bugle—The Yellow Iris—The Germander Speedwell

The Wild Strawberry (*Fragaria vesca*, L.).

The structure and the mode of reproduction of the Strawberry may be studied in any of the numerous species or varieties which are in cultivation, but perhaps better in the common Wild Strawberry of our woods and hedge-banks. The conspicuous white flowers of this plant are to be seen everywhere in April and May, while the fruits, which ripen in succession as the flowers fade, have the same construction as those of the cultivated Strawberry, though they are much smaller.

If a plant in flower be dug up and examined it will be found to possess a firm, woody, underground stem, covered with brown scales. This stem may be simple or branched. From it spring roots which grow down into the soil. At the end of the stem we find a rosette of foliage leaves and a single inflorescence. The inflorescence does not spring, as might perhaps have been expected, from the centre of the group of leaves, but stands to one side of this. It does not, in fact, belong to the same branch as that bearing the foliage leaves, but was formed in the centre of the rosette of leaves of the preceding season. These have now withered, and the inflorescence marks the end of the shoot on which they were borne. A bud in the axil of one of the leaves of last year has continued the growth of the plant in the present

season, and has produced the rosette of leaves we see. This shoot will end in the inflorescence of next year, which will be already formed before autumn although it will only grow to its full size after the leaves have withered and decayed. The underground stem of the Wild Strawberry is thus really made up of a succession of lateral shoots; and the mode of growth of the plant may be instructively compared with that of the Primrose.

The foliage-leaves are attached to the stem by a wide, sheathing base, to either side of which is joined a pointed, membranous stipule. These stipules never become leaf-like in appearance, but turn brown and, together with the leaf bases, remain after the leaf has fallen. It is the persistent stipules of the leaves of former years that give the scaly covering to the underground stem. Above the leaf-base comes a long and almost cylindrical leaf-stalk, which is often reddish and is covered with soft whitish hairs standing out from the surface. The leaf-stalk continues into the midrib of a leaflet, and to either side below this is a lateral leaflet. The leaf-blade is thus branched, consisting of three oval green leaflets with toothed edges.

As usual a bud is formed in the axil of each leaf. Those in the axils of some of the lower leaves straightway develop, not into leafy branches but into special shoots which are familiar as the " runners " of the Strawberry. The runner has greatly extended internodes, which are more or less red in colour and are hairy. It bears reduced scale-leaves at the nodes. Usually the bud in the axil of the first scale-leaf does not develop, but that in the axil of the second leaf grows into a leafy shoot, while from the node and the base of the shoot roots spring which attach the latter to the soil and ensure a direct supply of water and food-salts. The runner may continue its growth and start new shoots similar to the first. Owing to the length of the thin regions of the runner between them and the parent plant the new shoots are rooted at a distance from the latter and from one another. When they become separated from the parent by the decay of the runner they are already fixed in the soil, and established as independent plants. A little study of the growth of a strong Wild Strawberry plant on a bank which is not too thickly populated by other plants will show what an efficient method of

vegetative propagation the plant has in these specially modified branches.

The origin of the inflorescence and the explanation of its apparently lateral position has been already considered above. It is an erect cylindrical, hairy stem, bearing small and reduced leaves. The internodes are long. The leaf borne at the first node has the form of a small foliage-leaf, while that at the second node consists of the leaf-base with the stipules and a single small green leaflet. The main stem of the inflorescence continues above this second leaf, and ends in the flower which is the first to open. Branches are, however, formed in the axils of both the leaves and end in flowers, while further branching proceeds from the axils of the reduced leaves they in turn bear.

Each flower (Fig. 80) has a calyx of five pointed sepals, between and below which are five smaller green leaves. These are not a second series of sepals, but are probably derived from the stipules belonging to the five sepals. Since we might have expected to find a stipule to either side of each sepal instead of one pointed leaf between every two sepals, this explanation is not quite clear. The fact that flowers are often found in which a more or less complete division into two affects one or more of the outer segments supports the suggestion that each of them corresponds to two stipules belonging to adjacent sepals fused together. We shall meet with a similar state of affairs in the Common Avens, which is a not very distant relation of the Wild Strawberry.

FIG. 80.—Wild Strawberry. A, entire flower; B, flower cut in half. (After Baillon.)

The five white petals, which form the conspicuous corolla, alternate with the sepals. They widen out rapidly from the narrow base by which they are attached to the receptacle. The petals, unlike the other parts of the flower, are very readily shed, so that uninjured and fresh flowers should be chosen for study. Within the corolla come the numerous stamens, the yellow anthers

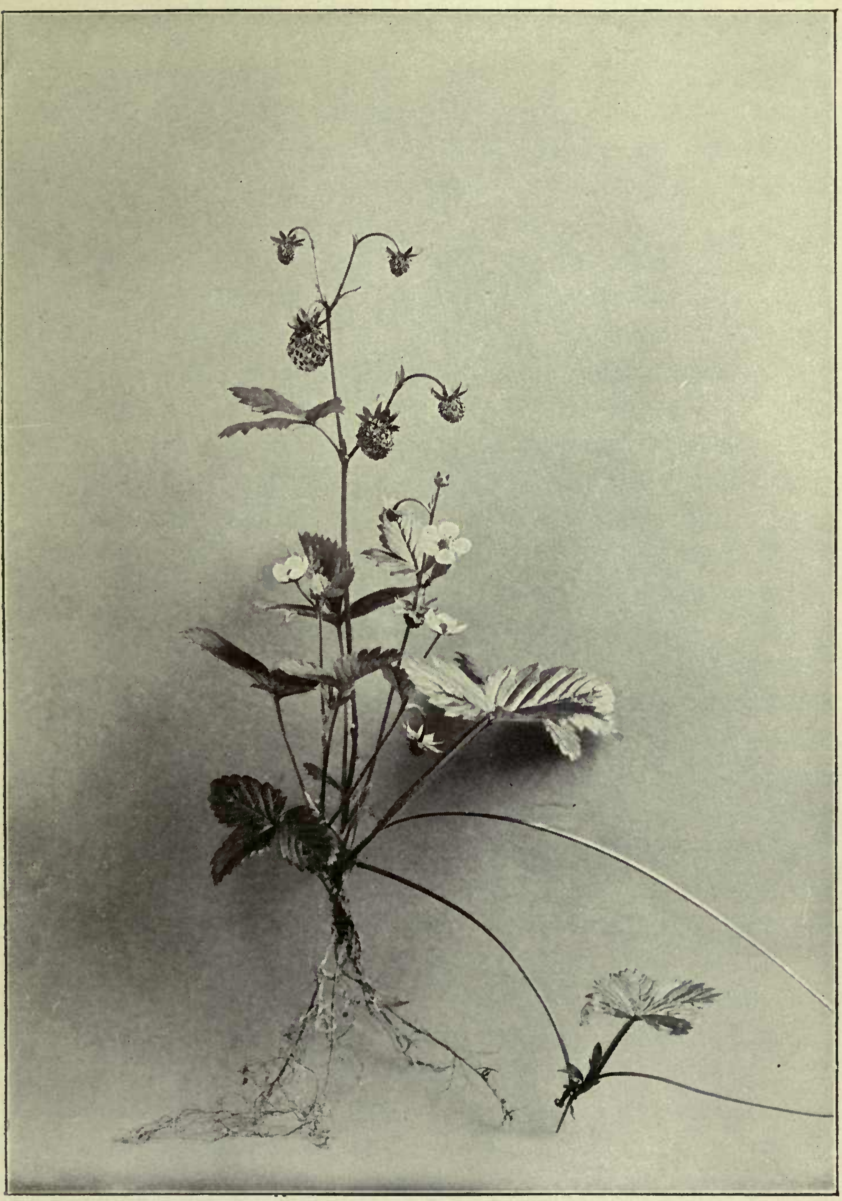


Photo by Henry Irving, Horley.

WILD STRAWBERRY (*Fragaria vesca*, L.)

of which contribute to the colour of the flower, while in the centre we find the hemispherical group of carpels. The carpels, like those of the Buttercup, are quite separate from one another. They are inserted on the globular end of the receptacle, and can be removed singly from this. If this is done and a carpel is examined with the lens, the small oval ovary will be seen. Springing not from the summit but from the side of this is the slender style which ends in the small stigma. The ovary contains a single ovule.

If another flower is cut in half with a sharp knife (Fig. 80, B) the sepals, petals, stamens, and carpels will be seen in their relative positions on the receptacle of the flower. In this a difference will be found from the Buttercup, with the flower of which that of the Strawberry may in many respects be compared. In the Strawberry the receptacle is widened just below the hemispherical end which bears the carpels, and the sepals, petals, and stamens all stand on this expansion.

The flowers of the Wild Strawberry, though not of large size, are conspicuous by reason of the expanded white corolla and the yellow centre formed by the stamens and carpels. They are visited by flies and bees in search of the nectar that is secreted by a region of the receptacle between the lowest carpels and the innermost stamens. The shallow, expanded shape of the flower allows the honey to be obtained by quite short-tongued insects. These alight on the petals, and on bending their heads inwards to reach the nectary will bring them in contact with the pollen shed from the open anthers and with the stigmas. On an insect, thus dusted with pollen, visiting a second flower it may carry pollen to the stigmas of the latter and so cross-pollinate it. This is a more likely result than self-pollination, for the stigmas ripen before the pollen of the flower is shed and are usually pollinated or have ceased to be receptive before the anthers open.

The fruit (Fig. 81) develops from the flower as a result of pollination. The petals fall off early, but the calyx and the withered remains of the stamens can be found at the base even of the ripe fruit. The fruit itself is almost entirely developed from the receptacle upon which the carpels were closely crowded. This enlarges and ultimately becomes succulent, while the colour

changes from green to yellowish white and then to red. As the receptacle increases in size the carpels become more separated from one another, and the true fruitlets, which are the result of the further development of the carpels, are distributed over the surface of the succulent receptacle. Each fruitlet is seated in a small depression of the latter, and consists of a firm yellow coat developed from the wall of the ovary and the single seed protected by this. The fruitlets do not fall off, but should an animal eat the succulent fruit their hard wall will protect the seeds against the action of the digestive juices. The structure of the strawberry, like that of other succulent fruits, is to be looked at in the light of this.

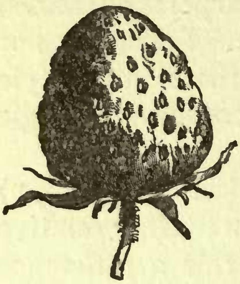


FIG. 81.—Fruit of the Wild Strawberry. (After Baillon.)

Both in the wild state and under cultivation the increase in number of individuals of the Strawberry plants is mainly effected by means of the runners. The spread of the plant to a distant spot must, however, be by seed, and in cultivation seedlings are raised in the search for new varieties.

THE BIRD'S-FOOT TREFOIL (*Lotus corniculatus*, L.).

The Common Bird's-Foot Trefoil is to be found in exposed and sunny grassy situations, where it forms extended patches conspicuous in May and June on account of the golden yellow flowers. The Greater Bird's-Foot Trefoil (*Lotus uliginosus*, Schk.) (Plate), while differing in some minor points, will serve equally for study. These plants get their name from the groups of pods which, borne on the slender stalk of the inflorescence, have some resemblance to the claw of a bird.

To understand the mode of growth of the plant, specimens should be carefully dug up, when the student will be surprised to find that what appeared to be a considerable colony of the plant is really a group of radiating branches attached to the one root. This is a long and stout tap-root, from which finer branches pass off into the soil around. On some of these branches little swellings, called root-tubercles, will be found (Plate).

These tubercles on the roots of this plant and its relatives are inhabited by Bacteria, which assist the plant to obtain the nitrogen it requires as food. At the upper end of the root we find a number of short, stout branches, from which thinner prostrate shoots in turn arise. It is the latter only that are obtained when a plant is pulled and not dug up, and, since they extend horizontally for some distance before they appear above the soil, it is easy to be misled into thinking that the whole plant has been obtained.

The underground parts of these shoots are whitish, and bear only small scale leaves at the nodes. On passing farther up the shoot the leaves gradually increase in size until the ordinary foliage-leaves are reached. The foliage-shoots are more or less erect. On them the leaves, which are exposed to the light, are larger. The stem is green, sometimes with a more or less intense red tint on the side exposed to the light. The terminal bud continues to grow and unfold new leaves, while in the axils of the uppermost foliage leaves the inflorescences occur as lateral branches.

The foliage leaves are pinnate and have no true stalks. The lowest pair of leaflets stands close to the insertion of the leaf on the stem. Separated from them by a short stalk come the other pair of leaflets and the single terminal leaflet. The leaflets of the lower pair are readily mistaken for stipules, but minute pointed stipules can sometimes be made out in addition to them.

The inflorescence has a long, thin, leafless stalk, at the upper end of which is a small green bract with three leaflets and a group of flowers. The short stalks of the flowers all spring from the same point, and the flowers bend over so as to face in the one direction. A single flower requires to be examined in great detail if the method of pollination is to be appreciated. What might appear to be trifling details of structure have their significance and use.

The flowers (Fig. 82, 1, 2) are irregular and stand in a definite position, so that an upper and a lower side can be distinguished. The calyx is composed of five sepals. These are united together to form a tubular structure, surrounding and holding in place the bases of the petals. As the free projecting tips of the sepals show,

one sepal stands in the middle line of the flower in front. The corolla consists of five petals, which alternate in position with the sepals, so that one stands in the middle line behind. This petal, which is larger than the others, is called the *standard.* Below this to either side stand two other petals called the

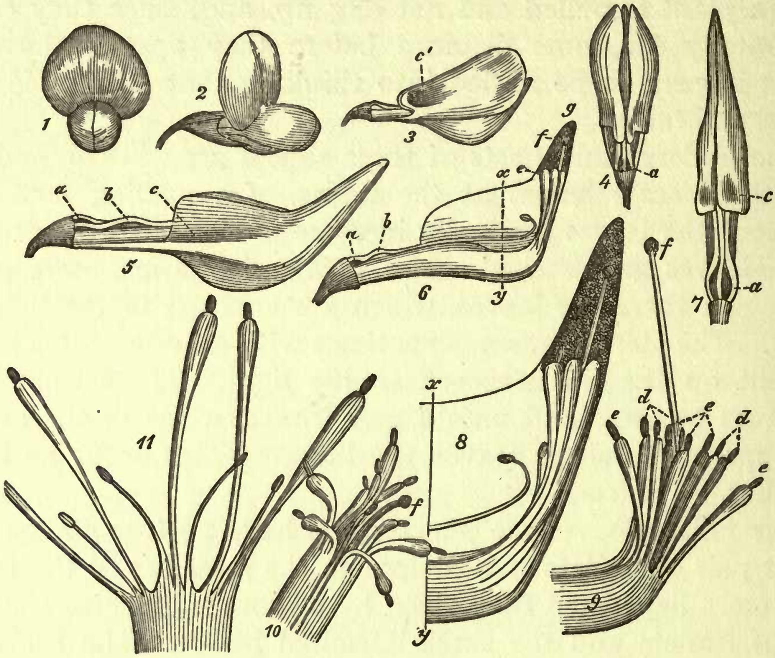


FIG. 82.—The Bird's-Foot Trefoil. 1, flower from in front; 2, flower from the side; 3, side view, the standard being removed; 4, the same, seen from above; 5, side view, the standard and wings being removed; 7, the same, seen from above; 6, one-half of the keel removed to show the position of the parts within; 8, front portion of 6, more highly magnified; 9, the stamens and style from the side; 10, the same from above; 11, the nine united stamens spread out. *a*, entrances to the honey; *b*, free stamen; *c*, depression in keel into which the bulge of the wing (*c'*) fits; *d*, the five short stamens; *e*, the five longer and club-shaped stamens; *f*, stigma; *g*, open tip of keel. (From Müller, *Befruchtung der Blumen.*)

wings, and overlapped by them and still lower are two more petals, which together form a boat-shaped structure known as the *keel.* The petals are of a bright golden-yellow colour. The standard, which wraps over the others in the opening bud, is more or less crimson on the outer side, and this gives the buds a vivid crimson colour. On the inner face the standard has a

GREATER BIRD'S-FOOT TREFOIL (*Lotus uliginosus*, Schk.).

I. Root showing the root tubercles. II. Flowering shoot.

III. Flower, seen from in front. IV. Flower, seen from the side.

number of narrow red lines converging to the centre of the flower.

If the calyx is carefully slit up and bent back the insertion of the petals will be visible. The narrow horizontal base of the standard is concave and overlaps the wings to some extent. Each wing is inserted by a very narrow stalk-like part; parallel to this on the upper side is an extension backwards of the broader portion. The base of this extension appears from the outside as a depression. From the inside it appears as a projecting bulge, which fits into a corresponding depression on the outside of the petal forming one-half of the keel (Fig. 82, 3, 4). The wings and keel are thus locked together, and the edges of the wings are also joined for a short distance above the keel. The two petals forming the keel are inserted separately by narrow stalks on the receptacle. The edges of the wider portions are joined both above and below (Fig. 82, 5, 7), so that the keel forms a flattened tubular structure tapering to the point, where the tube is open.

The stamens are completely enclosed in the keel, which must be slit up to show them. One stamen standing in the middle line behind is free from the other nine, the stalks of which are joined together to form a trough-like structure. The free portions of the filaments bearing the anthers spring from the margin of this; they occupy the up-turned tip of the keel. Five of the stamens are longer than the other five, and their filaments are swollen below the attachment of the anthers. As Fig. 82, 8 shows, these club-shaped ends of the filaments together fill up the narrowing tube formed by the keel. The anthers open early, so that the pollen is shed in the tip of the keel in front of this.

The green pod-like ovary is enclosed by the trough formed by the united filaments. The ovary stands almost horizontally, while the slender style is almost at right angles to it, and lies between the free portion of the stamens and extends beyond them (Fig. 82, 8). The style ends in the small stigma, which is thus surrounded by pollen near the tip of the keel. The ovary contains a number of ovules attached to the upper margin where the edges of the single carpel join together.

To complete the description of the flower it must be pointed out that the receptacle is widened out to form a shallow cup (cf. p. 106). Nectar is secreted around the base of the ovary, and is concealed within the tube formed by the stamens. Entrance to the nectary can only be obtained to either side of the base of the free stamen.

It might at first appear as if self-pollination were a necessary result of the stigma being surrounded by pollen in the tip of the keel. The stigma is not receptive, however, until it is rubbed, so that it remains unfertilised while the flower is opening and becoming ready for the visits of insects. The flower is visited especially by bees. These come in search of the nectar, to which they are guided by the converging red lines on the standard. The bee alights on the wings, and the weight of its body is transmitted to the keel owing to the interlocking of the petals. The keel will thus be depressed, its open tip resting against the under side of the body of the visiting insect. This depression does not extend to the stamens, so that the keel is forced down over the group of filaments, which fill its cavity as the piston of a syringe fills the cylinder. The effect of this is to force some of the pollen from the tip of the keel, and this pollen will be deposited on the region of the under surface of the insect. When the weight of the insect is removed the keel rises up and the mechanism is ready to work in the same way on another insect coming to the flower. When the keel is sufficiently depressed the stigma emerges and will rub against the same spot on the insect where pollen may have been deposited from a flower previously visited. The whole arrangement, in the study of which Fig. 82 will be found of great assistance, is beautifully adapted to render cross-pollination likely if the flowers are visited by insects. There is some reason to think that in the absence of the latter the flower's own pollen is effective.

The fruit of the Bird's-Foot Trefoil is, when ripe, a straight brown pod. This has the calyx at the base, but the other parts of the flower have fallen away. The pod contains a number of smooth round seeds like small peas, and opens by the two valves splitting completely apart.

THE DAISY (*Bellis perennis*, L.) AND THE FEVERFEW (*Matricaria inodora*, L.).

The Daisy is such a common and successful plant that it must be referred to. Owing to the small size of its flowers many of their features are difficult to make out in the Daisy itself, and their study may be supplemented by that of the Feverfew, in which the flowers are similarly constructed but somewhat larger.

FIG.—83.—Daisy bearing inflorescences. (After Baillon.)

The Daisy occurs everywhere in waste and grassy ground, and is a successful weed in lawns. Its mode of growth will be best shown in specimens not from a well-mown lawn, but from some spot on which the plants have grown for some years undisturbed (Fig. 83). In such a plant of medium size the root-system will be found to consist of a number of stout, cylindrical roots bearing finer branches. These roots spring from the lower end of a short, stout stem. The latter may form a single leafy shoot, but more commonly the shoot is branched and a number of leafy shoots extend on all sides from the main stem, in connection with the root-system. These branches lie along the soil, and their older parts, like the surface of the main stem, are marked by the scars of fallen leaves. Nearer the tip of

each shoot comes the rosette of foliage-leaves, which are closely crowded on the stem. Each foliage-leaf is simple, the leaf-stalk narrowing slightly from the leaf-base and then widening out into the dark green leaf-blade, the edge of which has a few teeth. The surface of the leaves and stem is sparsely covered with short, coarse hairs.

The plant, according to its size, bears one or many inflorescences or flower-heads, the so-called "flowers" of the Daisy. Each of these stands at the end of a long, bare, green stalk, and some little care will be needed to make out the way in which the shoot bearing a number of flower-heads is constructed. It will be found that the shoot always ends in a flower-head. Its further growth is continued by a lateral bud, which forms a shoot bearing two or three leaves and in turn ends in an inflorescence. These therefore are only apparently lateral.

When growing on a lawn the Daisy plants spread vegetatively by the production of short prostrate branches. In this way the patches extend, and the growth of the plant is further favoured by the rosettes of leaves pressed close to the ground escaping destruction by the mower.

Each flower-head has a long, cylindrical, leafless stalk, which expands into a conical upper end. This is best shown on splitting a flower-head in half, when the little flowers will be seen closely crowded together upon the surface of the expanded stem of the inflorescence. On the outside of the inflorescence we find a series of small green leaves. These are the bracts, and covered in all the developing flowers when the inflorescence was in bud. The flowers or florets are of two kinds. Little yellow tubular florets are crowded together, forming the centre or disc of the flower-head. Around them comes a circle of florets of the ray, the white corollas of which are drawn out into strap-shaped structures; this renders the flower-head as a whole more conspicuous.

If the general mode of growth of the plant and the nature of the so-called flowers are appreciated, the details of the flower and fruit, though they can be made out in the Daisy, will be more easily studied in a plant with similar inflorescences but larger florets. For this purpose we shall take

THE FEVERFEW (*Matricaria inodora*).—This plant is a common weed in waste places, especially in cornfields throughout the country. Another species of the genus, *M. chamomilla,* is closely

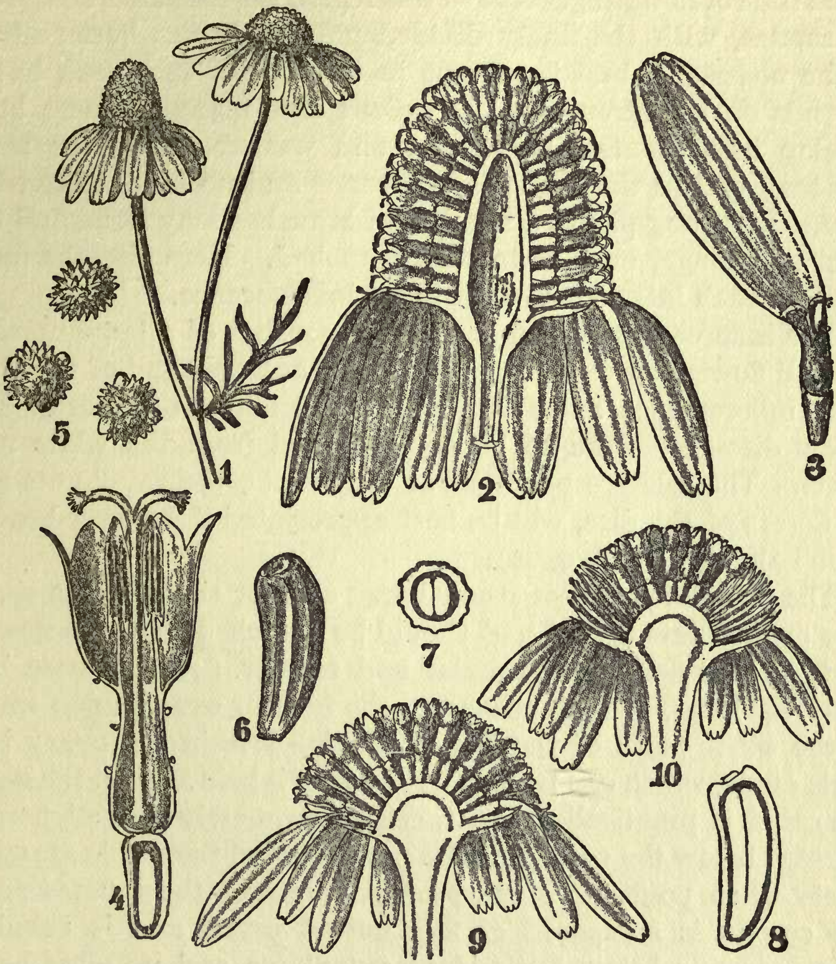


FIG. 84.—1–8, *Matricaria chamomilla* ; 9, *Matricaria inodora* ; 10, *Anthemis arvensis.* 1, shoot with two inflorescences ; 2, 9, 10, flower-heads cut in half ; 3, ray-floret ; 4, disc-floret cut in half ; 5, pollen grains, highly magnified ; 6, fruit ; 7, fruit, cut across ; 8, fruit cut in half, lengthwise. (After Schumann.)

similar and will do equally well for the study of the flowers. Both are represented in Fig. 84. The Feverfew is an annual, and the plants attain a smaller or larger size, with a less or more branched shoot. It flowers in July and onwards until autumn.

The vegetative organs may be very briefly described. The plant has a stout tap-root, and at the base of the shoot are a number of leaves closely crowded together. These have usually withered at the time of flowering. Above this region the shoot has elongated internodes, with the finely divided pinnate leaves borne singly at the nodes. A bud is present in the axil of each leaf, but it depends on the strength of the plant how many of these buds develop into shoots. In smaller and weaker plants the main axis may end in the single inflorescence and no lateral branches form. In strong plants a number of branches may form, and the lower and longer ones be in turn branched. Here also the main axis and each lateral axis ends in an inflorescence.

The inflorescence, as in the Daisy, consists of a large number of small flowers crowded together on the enlarged end of the stem of the inflorescence, and surrounded by a number of bracts. The yellow disc-florets are to be distinguished from the white ray-florets. The relative positions of the bracts, the ray-florets and the florets of the disc, will be best appreciated if a flower-head is cut in half (Fig. 84, 2, 9, 10).

The disc-floret is best studied first, and for this purpose single fully open florets (Fig. 84, 4) should be detached from the flower-head. These florets are tubular and regular. At the base is a relatively large, whitish structure, the inferior ovary, upon which all the other parts of the flower stand. Within the ovary is a single ovule, which can be seen if the ovary is held against the light. The calyx is practically absent, consisting merely of a slight rim or fringe below the corolla. The protection of the whole group of florets when young is given by the bracts of the inflorescence. The corolla is composed of five united petals and is tubular. It is narrower below but widens out above and its edge bears five yellow teeth, which are the free tips of the petals. On looking into the corolla a yellow body composed of the five anthers will be seen, and in old flowers the two lobes of the stigma will be found projecting above this. The determination of the relative positions of these parts requires delicate manipulation and the assistance of a good lens. It will be understood from Fig. 84, 4, which represents a mature floret cut through longitudinally. The five stamens, which alternate in position with the teeth of

the corolla, spring on slender stalks from the inner surface of the latter just where it widens out. The filaments are separate and distinct, but the anthers are joined together edge to edge and shed their pollen into the tube thus formed. The two lobes of the bifid stigma are at first closed together, and are gradually pushed up the anther tube by the growth of the style, only unfolding when the pollen has all been swept out.

The florets of the ray (Fig. 84, 3) have also an inferior ovary and practically no calyx. The lower part of the corolla is tubular, but the upper portion is prolonged on the side away from the centre of the inflorescence into a white strap-shaped structure. The free edge of this shows three minute teeth, which indicates that three only of the five petals are concerned in the outgrowth. A style and bifid stigma stand in the centre of the ray-floret, but no stamens are present.

The disc-florets are thus regular and have both stamens and pistil, while the florets of the ray are irregular and are purely female.

Insects visit the flower-heads, which are conspicuous objects, in search of pollen and of the nectar secreted at the base of the tubular corolla. In doing this they will come in contact with florets of various ages. In those in an earlier stage pollen will be swept out of the anther tube and the stigma will not have appeared. In those at a later stage the pollen will have been removed, and the receptive stigma will be exposed. The probability is therefore that the stigma will be pollinated from another floret, and possibly from another plant. Cross-pollination must take place in the case of the ray-florets, but the florets of the disc may be self-pollinated if cross-pollination fails. This comes about by the curving backwards of the lobes of the stigma in old flowers, as was described for the Dandelion.

The ovary develops into a one-seeded fruit (Fig. 84, 6, 7, 8), which ultimately becomes detached from the flower-head but has no special means of dispersal.

The study of the Dandelion, Daisy, and Feverfew will enable the student to understand the construction and mode of pollination of the flower-heads and flowers of a large family of plants, to which belong, for example, the Thistles, the Hawk-weeds, and the Ragworts.

THE PERENNIAL RYE-GRASS (*Lolium perenne*, L.).

This common Grass can be found in abundance in any piece of grass land, as well as on waste ground and by roadsides. Its study will prepare the student for the examination of other grasses. The Perennial Rye-grass can be recognised among most common grasses by the long flattened inflorescence. The main stem of this bears some eight to twenty flat "spikelets," which are placed edgewise on the stem and alternate on the two sides of this. Plants with inflorescences should be dug up and their roots washed. If, as may happen in cold, wet weather, no open flowers are found a number of inflorescences can be placed in water and kept in the house, when the flowers will open.

The plant consists of a group of stems attached to the soil by numerous, fine, branched roots springing from the bases of the various stems; no main root can be distinguished. Each shoot bears at the base two or three leaves separated by short internodes. In the axils of these leaves are buds, and the further development of the latter increases the number of shoots of the plant. The formation of new shoots, and in consequence the local spreading of the plant, is increased by cutting back the flowering shoots. This is the explanation of the advantage of regularly mowing any lawn or piece of turf. The general appearance and mode of growth of the plant is so characteristic of all common grasses that plants with slender stems springing in a group from the base and bearing long narrow leaves are often spoken of as grass-like.

The shoot has long cylindrical internodes, and at each node a single leaf is borne. The leaves alternate on opposite sides of the stem. The nodes are marked by swellings of the base of the leaf-sheath (Fig. 85, 2). This is of considerable length and surrounds the stem closely, though the sheath is not joined to form a tubular structure. Owing to the length of the sheath the leaf-blade stands out from the stem some distance above the nodes. Just where the blade joins the sheath a delicate semi-transparent fringe, which fits closely against the stem, will be found. This is characteristic of the leaves of most grasses, and is called the *ligule*. The leaf-blade is long and narrow, and tapers to a point.

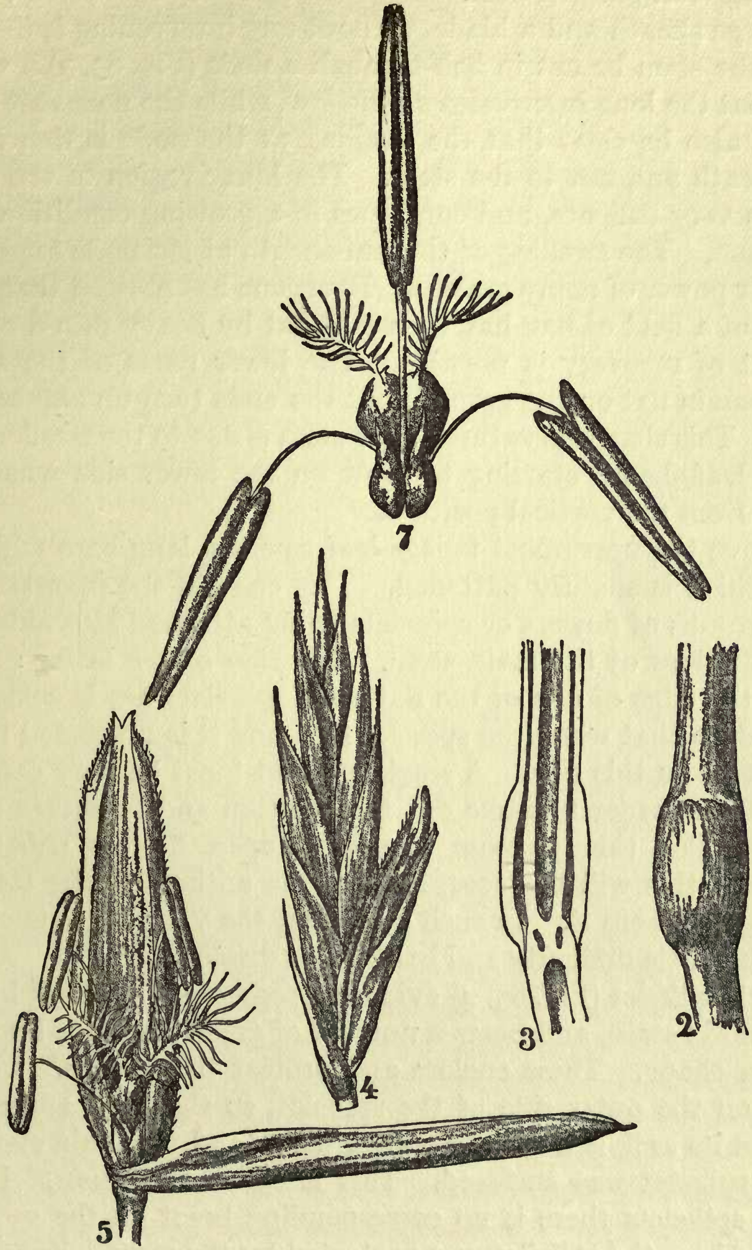


FIG. 85.—Perennial Rye-Grass. 2, node; 3, node cut through, lengthwise; 4, spikelet; 5, flower between the upper and lower pales, the latter bent away to show the lodicules, stamens, and pistil; 7, parts of the flower removed from the spikelet. (After Schumann.)

The veins run parallel in it. We thus find the leaves to consist of a large sheath and a blade, without any intervening leaf-stalk.

If the stem be cut in half through a node (Fig. 85, 3) it will be seen that the long internodes are hollow, while the nodes are solid. It will also be clear that the swelling at the node is due to the leaf-sheath and not to the stem. The lower region of the internode is very delicate, and continues in a growing condition for a long time. The swelling of the leaf-sheath at the node explains a familiar power of many grasses. Everyone has noticed that when a part of a field of hay has been laid flat by heavy rain a certain amount of recovery is possible. The lower parts of the shoots may remain flat on the ground, but the ends turn up and become erect. This sharp curvature of the stem is due to the swollen base of the leaf-sheath starting to grow on the lower side when displaced from the vertical position.

Above the uppermost foliage-leaf comes a long bare region of stem which is slightly flattened. This ends in the inflorescence, small groups of flowers or spikelets being attached alternately on opposite sides of the main stem. The side of the latter against which the edge of one of the flattened spikelets lies is somewhat grooved, so that when the spikelet is young it is protected by the main stem on this side. A single spikelet must be very carefully examined in order to make out the position and structure of the flowers. For this purpose one with open flowers should be selected; this will be recognised by the anthers of the stamens hanging out from it. In such a spikelet the various parts can be seen with little difficulty and hardly any dissection.

Each spikelet (Fig. 85, 4) evidently represents a lateral branch of the main stalk, and bears a number of green leaves or bracts of peculiar shape. These enclose and protect the flowers. Lowest of all, on the outer side of the spikelet, so that this appears to stand in its axil, is a bract between which and the main stem the young spikelet was enclosed. This is called the *glume*. In the lateral spikelets there is no corresponding bract on the opposite side, for here the spikelet was protected by the stem. But in the spikelet which terminates the inflorescence two glumes will be found enclosing the rest of the spikelet between them. This is the condition most commonly met with in the spikelets of

grasses. No flowers stand in the axils of the glumes, but on the slender stem of the spikelet above them they will be found placed alternately on the side turned towards the main axis of the inflorescence, and on the side away from this.

Each of the little flowers is a side branch of the thin stem of the spikelet itself, and appears to be enclosed between two narrow concave bracts. The short stem of the flower stands in the axil of the lower bract, which is called the *inferior pale*, and the other bract, the *superior pale*, is placed a little higher on the axis of the flower facing the inferior pale. The inferior pale is concave, and overlaps the margins of the superior pale. The latter is thin and translucent at either edge, and in the middle line; the middle portion that fits against the flower immediately above is not only flattened but concave. These two protecting bracts completely enclose the structures forming the flower itself until the moment of flowering.

When this takes place, the pales diverge like the two valves of a shell, and by pulling them farther apart we can see all the parts of the very simple flower (Fig. 85, 5). There are three stamens and a pistil. The stamens have large yellow anthers, which hang freely from the spikelet on delicate filaments. The pistil, which stands in the centre of the flower, consists of a small greenish, pear-shaped ovary bearing at its upper end to either side a feathery stigma. The stigmas are delicate, white, plume-like structures exposing a relatively large surface.

There is no trace of either calyx or corolla of the usual kind surrounding the pistil and stamens. Two little structures have, however, yet to be recognised. At the lower side of the flower, *i.e.* at the base of the inferior pale, are two pale translucent bodies, swollen below and pointed above (Figs. 85, 5, 7). These delicate structures are called the *lodicules*, and perform an important function. At the time of flowering they swell, and it is their enlargement that forces the two pales apart, and thus exposes the parts of the flower. It is possible that the lodicules represent the perianth of the grass flower.

There are some eight or ten flowers in each spikelet. In comparing various grasses, the flowers of which are very similar, it is important to ascertain exactly the construction of the spike-

let, and the student will do well to thoroughly master that of the Rye-grass by examining and drawing a number of specimens.

We can now consider how the flowers are pollinated. As seen above, all the parts remain enclosed by the pales till the moment of flowering. This usually takes place on a bright warm day, and the anthers are quickly carried clear of the spikelet by the growth of their filaments, and open, thus liberating the pollen. This is shed as a dusty substance, the separate grains floating freely in the air. Some of these pollen-grains may come against the stigma of a flower on the same or more probably another inflorescence. The plume-like stigmas are well fitted to catch the pollen grains. The flowers are thus pollinated by help of the wind, and this explains their inconspicuousness, the absence of nectar, and the fact that they are not visited by insects.

The result of pollination is that the ovary, which has one cavity and contains a single ovule, develops into the fruit. The seed-coat of the one seed is so closely united with the wall of the fruit that they together form a single brown layer around the seed-like fruit. This contains an embryo lying against one side of the fruit near the lower end, and a relatively large mass of tissue containing food material. The fruits of most grasses are very similar, and a grain of Wheat will afford an interesting example for study.

The Garden Sage (*Salvia officinalis*).

The Garden Sage is commonly grown in the vegetable garden as a pot-herb, and other species, which well serve for study, are cultivated for the beauty of their flowers. The plant is a small perennial shrub, never attaining a large size, since the smaller branches die back each winter leaving the main stem and branches, the buds of which unfold in the next season. Owing to the presence of glandular hairs on the leaves the plant has a strong aromatic scent.

The stem is square and covered with short hairs. The leaves are borne in pairs at the nodes, the successive pairs alternating. Each leaf has a grooved leaf-stalk extending from the widened leaf-base to the leaf-blade, into which it continues as the midrib. The elongated, oval blade gradually widens out at the base, and

THE GARDEN SAGE (*Salvia officinalis*).

contracts at the tip to a more or less sharp point. The upper surface, deeper in tint than the lower which bears the glandular hairs, is thrown into small folds, and the margin is bordered by small rounded teeth.

It is in the flowers of the Sage, however, that the chief interest of its study lies, and these should be carefully compared with the flowers of the Dead-nettle described above, which is a related plant. The inflorescences are borne at the ends of some of the vegetative shoots (Plate). The bracts are small and inconspicuous, but are arranged like the leaves in alternating pairs. In the axil of each bract stands a group of stalked, blue flowers. The middle flower of the group is the first to open, then one stand-

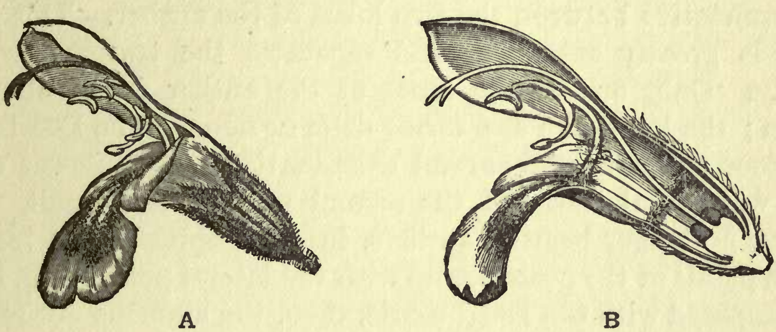


FIG. 86.—Garden Sage. A, flower seen from the side ; B, flower cut in half. (After Baillon.)

ing on either side, and then a bud between this and the central flower.

Each of the irregular flowers (Fig. 86) has a short stalk, and can be divided into similar halves by a plane passing from front to back. The calyx is composed of five united petals, and is distinctly two-lipped. As shown by the pointed free tips, three sepals go to make up the posterior lip and two the anterior lip. Its colour is green, the ribs being purplish. The corolla is of a bright blue colour, and is also two-lipped. It is made up of five united petals, which alternate in position with the sepals. The posterior lip forms a hood protecting the anthers and stigma ; it is composed of two petals. The anterior lip is broad and is formed of three petals. The middle one forms a broad two-lobed projection, which serves as a landing-place for insects.

So far the flower resembles in general construction that of the Dead-nettle. If the corolla is removed and slit up along the middle line in front the stamens will be seen attached to its inner surface. The two well-developed stamens join the corolla opposite the lines of junction of the anterior and lateral petals, which form the lower lip, and have a very peculiar shape. Each has a stout, white, cylindrical filament, the shape of which is shown in Fig. 86, B. A curved portion is fixed at right angles to the free end of the filament, like the cross-piece of a T. At the forwardly directed end of this is a yellow anther-lobe and at the other a small knob. Comparison of this peculiar stamen with that of the Dead-nettle will show that the cross-piece corresponds to the connective between the two lobes of the anther. This in the Sage is greatly extended, and separates the two anther-lobes widely. Only one of the lobes of the anther forms abundant pollen; the knob-like one forms little or none. The Dead-nettle had four stamens, and careful examination of the flower of the Sage will reveal traces of the second pair as two small, white, bodies, no longer bearing anthers, inserted opposite the junction of the petals of the posterior lip with the lateral petals (Fig. 86, B). As compared with the Dead-nettle, then, the stamens are reduced in number to two, and these are peculiarly developed so that only one-half of the anther forms pollen. Another feature to be noted in the corolla-tube when slit open is a ring of white hairs which stand at the junction of the lower colourless portion of the tube with the upper coloured part. These hairs serve to protect the nectar, which is secreted by the large purple-coloured nectary at the base of the ovary, and accumulates in the lower portion of the corolla-tube.

If the corolla is carefully removed from a flower the style and stigma, which lay beneath its posterior lip, will remain projecting from the calyx. The tip of the style bears a two-lobed or forked stigma, the lobes of which diverge only in the later stage of flowering. On splitting the calyx open the style will be found to spring from the centre of the ovary, which is composed of four, rounded, green lobes. In each of these is a single ovule.

Having dissected one or two flowers and studied the form

and relative positions of all the parts, an intact flower should be taken and the relation of the parts when undisturbed carefully considered. We have seen that the nectar is to be found at the base of the corolla-tube, protected by a ring of hairs. The curved style lies against the posterior lip, and the stigma, which at first is closed, projects beyond the anthers. The elongated connective is balanced on the end of the filament, so that the two fertile anthers lie side by side beneath the posterior lip, while the sterile knobs stand right in the path leading to the nectar. Each connective thus forms a lever balanced on the filament, the shorter arm of the lever bearing the sterile knob. If now an insect such as a bee alights on the lower lip and, inserting its head, passes its proboscis down to the nectar, it is easy to understand what will happen. The downwardly directed halves of the anther will be pressed upwards out of the way, and this will cause the other arms of the levers to descend. This movement will bring the pollen-containing half of the anther in contact with the insect's back, and pollen will thus be deposited on the latter. The action of the insect can be imitated by passing a needle or bristle into the corolla.

In older flowers, that will have already shed their pollen, we find that the style has grown longer and its tip has curved down. The two lobes of the stigma now gape apart, and are ready to receive pollen on their inner faces. If a bee, which has had pollen deposited on its back in visiting another flower, comes to a flower in this later stage, the stigma will brush against the region of its back on which the pollen was placed. The flower will thus be cross-pollinated.

The flower of the Sage is a highly specialised arrangement for ensuring cross-pollination by the agency of bees visiting the flower for nectar. In correspondence with the precision of the mechanism, we find that the amount of pollen needed is reduced. As compared with the Dead-nettle, two stamens have become functionless, and only one half of the anther in each of the other two forms pollen. Other species of *Salvia* cultivated in the flower garden will show even more specialised arrangements for pollination on the same principle.

The fruit consists of four nutlets, each developed from one

lobe of the ovary and containing a single seed. The developing fruit can be seen at the bottom of the calyx, all the other parts of the flower having fallen off after pollination.

Cuckoo Flower (*Lychnis flos-cuculi*, L.) and the Red Campion (*L. diurna*, Sibth.).

The Cuckoo flower or Ragged Robin and the Red Campion are closely related. It is of interest to study them together and compare their flowers. The Ragged Robin is usually found in damp grassy ground, flowering from June onwards; it is often found along with the Lady's Smock (*Cardamine pratensis*), which is also often called Cuckoo flower, and has been described above. The plant is perennial, fixed in the ground by a strong main root, and also producing roots from the bases of the branches. The latter develop from the axils of the lower leaves, and in this way the number of stems produced yearly by a plant increases.

The leaves at the base of each shoot are closely crowded, but resemble the leaves borne higher on the shoot where the internodes are well developed. The stem between the pairs of leaves is marked by six longitudinal ridges, and bears whitish hairs pressed closely against the surface. The nodes are swollen and have a reddish tint, which also extends over the lower internodes. Two leaves are borne at each node, placed opposite to one another; their sheathing bases unite around the stem. There is no leaf-stalk, and the blade is of a simple elongated form with a well-marked midrib, and stands almost erect beside the stem. The pairs of leaves inserted at successive nodes alternate in position.

As we pass upwards to the region of the inflorescence we find that the bracts resemble the leaves, but are smaller, more pointed, and of a brownish red colour. The branching of the inflorescence is very characteristic. The main stem ends in a flower which is the first to open, and growth is continued by two branches which spring from the axils of the uppermost pair of bracts. Each of these branches ends in a flower, and below this bears a pair of bracts. Branching similarly proceeds from the buds in the axils of these bracts.

The flower itself consists of calyx, corolla, stamens, and pistil.

The slender flower-stalk has a brownish red colour. The five sepals, the free tips of which project as pointed teeth, are united to form a wide tubular calyx. The midrib of each sepal appears as a brownish red ridge on the outside of the pinkish calyx, and a similar rib runs down midway between each of the first set, so that ten ridges are present. The tubular calyx holds together the five free petals, the insertion of which is seen on splitting open the calyx to be separated by a distinct internode from that of the sepals. In each petal we distinguish a narrow stalk-like part from the pink-coloured portion, which expands above the mouth of the calyx. The wider terminal portion is deeply notched, and each half is in turn divided. Just where the stalk passes into the expanded part two upgrowths, pink at the base, whitish above, spring from the upper surface of each petal. These upgrowths stand edge to edge, and may be compared with the corona of the Daffodil.

There are two whorls of five stamens, the outer standing between the petals and the inner ones opposite to the petals. In the centre of the flower is the green ovary bearing five long whitish stigmas. If the ovary is carefully opened the numerous ovules will be found to be borne on a central plug projecting into the cavity, and not connected with the wall except at the base of the ovary (cf. Fig. 56, D).

Nectar is secreted at the base of the stamens, and the flowers are visited by a number of insects, especially by butterflies and moths, in search of it. To understand the effect of the insects passing from flower to flower it is necessary to follow the order of maturing of the stamens and stigmas. The five outer stamens ripen first, and while the pollen is being shed their anthers occupy the entrance to the tube of the flower. As the other five stamens in turn mature, their anthers take the same position, and when they have withered the five stigmas, which till now have been small and undeveloped, grow up and fill the entrance to the flower. When an insect visits a flower in the earlier pollen-shedding stage it will carry away pollen on its proboscis or head; on going to a flower in the later stage, in which the stigmas are mature, it will deposit pollen on these but will not receive pollen from the flower. Cross-pollination is therefore likely to take

place, but in default of this the stigmas as they develop may come in contact with pollen grains remaining adherent to the withered anthers of the same flower, and so be self-pollinated.

After pollination the ovary enlarges and becomes the fruit. This is surrounded by the calyx, while the other parts of the flower wither and fall away. The fruit, when mature, opens by its dry wall splitting at the tip into five teeth, which curve backwards and leave a wide opening into the single cavity. From this the little seeds developed from the ovules can readily be shaken.

The Red Campion (*Lychnis diurna*) occurs, often in large numbers, on sunny banks or in partially cleared woods. The mode of growth of the plant is very similar to that of the Ragged Robin, and the branching of the inflorescence is the same. The stem is round and hairy, and the leaves are larger and softer and bear short hairs on both surfaces.

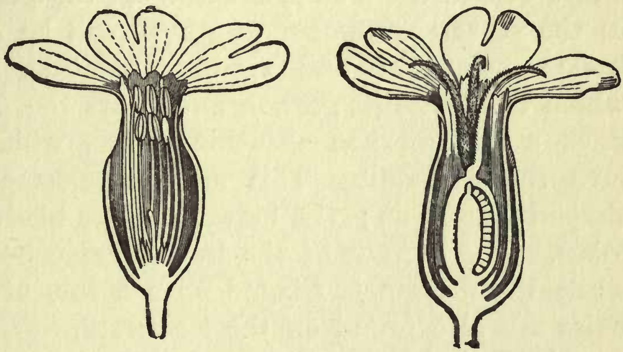
In collecting material for study two kinds of plants will be recognised. These are best distinguished by looking at the flowers. In the opening of the corolla of all the flowers on some plants the anthers shedding the pollen will be seen, while in the same position in other specimens are the five whitish stigmas. Several whole plants of each kind should be collected, when it will be seen that, though alike in mode of growth, arrangement of leaves, and branching, the plants bearing flowers with stamens are less robust and have thinner stems and smaller leaves than those bearing pistillate flowers.

The two kinds of flowers (Fig. 87) require separate examination. In the staminate flowers we find a somewhat distended calyx bearing at the margin five pointed teeth. The corolla consists of five rose-pink petals resembling in shape those of the Ragged Robin, but not fringed in the same way. Within the petals are ten stamens, but there is no pistil in the centre. Sometimes five little projections are present within the ring of stamens, and occasionally a flower is found with a rudimentary ovary in this position. The nectar is secreted on the inner side of the bases of the filaments; it is protected by the hairs growing from the lower parts of the latter.

The other type of flower (Fig. 87, B) is similar as regards the calyx and corolla, but there are no obvious stamens. Within

the corolla is the large pistil. This consists of the green ovary surmounted by five white stigmas, which are receptive to pollen on their inner faces. The ovary, as in the Ragged Robin, has a single cavity, and the ovules are borne on a central projection from the base. The position of the partitions, which are not developed, is indicated by ridges projecting from the inner surface of the wall of the ovary. At the base of the ovary are ten little pointed bodies. There are the rudiments of the stamens, which are here arrested at an early stage of their development. The nectar in this flower is secreted around the base of the ovary.

In contrast to the Ragged Robin, the Red Campion has flowers of two kinds, pistillate and staminate, on distinct individual plants. Comparison with related plants leaves no doubt that this has come about by the arrest of the stamens in the flowers of some plants and of the pistil in those of other individuals, though we know nothing of the cause of this difference between the individual plants. Evidently self-pollination is impossible in the Red Campion, but the long-tongued insects, especially butterflies, which come to the flowers in search of the deeply placed nectar, will carry pollen from the male or staminate flowers to the stigmas of the female or pistillate flowers. The fruit which develops from the ovary of the pistillate flower is of similar construction to that of the Ragged Robin.



A B

FIG. 87.—Flowers of the Red Campion cut through lengthwise. A, staminate flower; B, pistillate flower. (After Baillon.)

While in the Ragged Robin we have flowers with both stamens and pistil, the development of the stamens before the stigmas were mature almost prevented self-pollination. The separation of the two sexes on distinct plants, as in the Red Campion, renders self-pollination impossible.

The White Meadow Saxifrage (*Saxifraga granulata*, L.) and the London Pride (*Saxifraga umbrosa*, L.).

In damp grassy land and on banks in May and June the White Meadow Saxifrage may be met with. It is not quite so common as most of the plants described here, but is of interest in a number of ways, and should be carefully studied if it is found. Specimens should be dug up with care, since the parts in the soil will be found as interesting as those above it.

The short underground stem bears some brown roots, and has clustered around it a number of pink spherical bodies, to the study of which we shall return. If the plant is examined early in the season a number of leaves will be found springing close beside one another and forming a rosette at the base of the shoot, which continues its growth and bears the flowers. These leaves have a well-marked sheathing base, which narrows gradually into the leaf-stalk. This again widens out into the kidney-shaped leaf-blade ; the margin of the blade is cut into rounded lobes. The surface of the leaf is hairy both above and below, while the margin is fringed with a row of longer hairs. Short hairs are also found on the leaf-stalk.

The cylindrical stem above the rosette of leaves bears a few leaves separated by long internodes. The leaves become successively simpler in form, and have shorter stalks, till we come to the reduced leaves or bracts on the inflorescence. The surface of the stem is sticky, owing to the secretion formed in the small globular heads of the numerous short hairs covering it. A little careful observation will show that the main stem of the inflorescence ends in the flower which is the first to open. From the axils of the two highest bracts branches arise that also end in flowers, and each branch in turn bears another flower in the axil of its uppermost bract.

The flowers themselves are fairly large, and when fully open are conspicuous. The flower-stalk widens into a green hemispherical region, which will be found to enclose the base of the ovary. On the margin of this dilated portion the five sepals are situated. These are rather large, and green ; they are covered on the outer surface with glandular hairs similar to those borne on

Photo by Henry Irving, Horley.

LONDON PRIDE (*Saxifraga umbrosa*, L.)

the stem. Alternating with the sepals are five white petals, the main veins of which, converging towards the base, are of a greenish yellow tint. When the sepals and petals are removed ten stamens will be visible, five of which stand slightly farther out than the other five. It is remarkable that the five outer ones are those standing opposite to the petals. The anthers on opening expose the yellow pollen. In the centre of the flower are two styles, which join together lower down. On cutting a flower in half, so as to cut through both the carpels, it will be found (Fig. 88) that the greater part of the ovary, formed of the two united carpels, is enclosed within the expansion of the floral receptacle noticed from the outside of the flower. The upper parts of the two carpels separate and form the styles, which taper somewhat till they end in the enlarged stigmas.

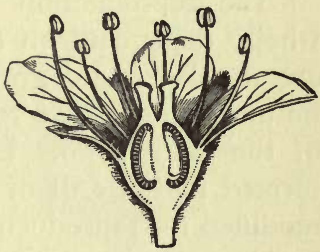


FIG. 88.—Flower of the White Meadow Saxifrage cut in half in the plane of the two carpels. (After Baillon.)

If a number of flowers of different ages are examined the order in which the stamens and stigmas mature will be ascertained and the way in which the flower is pollinated can be understood. When a flower opens none of the stamens have shed their pollen, and the styles are short and stand close together in the centre of the flower; their stigmas are still immature. The stamens of the inner whorl mature first, and as they open their anthers bend inwards and stand immediately above the pistil. As the pollen is shed these stamens gradually bend away from the centre of the flower. The anthers of the outer whorl of stamens next take up this position and open. The opening of the anthers and shedding of the pollen takes two or three days, and during this period the styles with the undeveloped stigmas remain close together. Then the styles elongate and diverge from one another, and the expanded stigmas develop. The flower thus passes through a stage in which it is shedding pollen, but has immature stigmas, to a stage in which the pollen is all shed, but the stigmas are mature and ready to receive pollen.

The conspicuous flowers are visited by flies and small bees,

which come in search of the nectar, secreted by the upper surface of the ovary and protected in the centre of the flower. The insect visitors on passing from flower to flower will tend to effect cross-pollination, carrying pollen from flowers in the earlier stage to flowers in which the stigmas are receptive. Should cross-pollination fail, the stigmas, as the styles bend apart, may come in contact with the stamens and so receive some pollen from their own flower.

The half-inferior ovary has two chambers, and in each a large number of ovules are contained, borne on a swelling of the partition. The pistil develops into a dry fruit, which splits in the plane of the partition and liberates the small sculptured seeds.

The reproduction of *Saxifraga granulata* is not, however, wholly dependent on the seeds. A number of individual plants are usually found growing close together, and their origin will be understood if we return to the small pink bodies at the base of the main stem. Each of these is a small shoot, doubtless formed in the axil of one of the lower leaves, and is specially modified for reproducing the plant. It consists of a short stem bearing closely crowded pink scales; these are leaves modified for the storage of food material. The little shoot thus resembles a small bulb, and is called a *bulbil* (Fig. 89). When isolated in the ground the bulbils grow further at the expense of the food material stored in them. Each forms a stem bearing foliage-leaves and flowers. At the base of a plant which has originated in this way the remains of the bulbil will be found, and, as has been seen, new bulbils will be developed on the lower part of the shoot. The plant is probably reproduced in the same spot year after year by means of the bulbils, though its spread to new positions must be effected by means of the seeds.

The London Pride (*Saxifraga umbrosa*) is familiar in all gardens in town or country. It belongs to the same genus as the White Meadow Saxifrage, and is found wild on the mountains of the west of Ireland, where it flowers in June and July. Since it is more easily obtained than *Saxifraga granulata*, attention will be briefly directed to its chief features.

The general appearance of the plant when in flower is repre-

sented in the plate, which shows that the foliage-leaves form a close rosette at the base. The fairly long leaf-stalk widens out into a leaf-blade, the margin of which is cut into rounded lobes. The margin of the leaf-stalk bears hairs, and glandular hairs are scattered over the surface of the cylindrical stalk of the inflorescence and more closely on the finer branches bearing the flowers. Small bracts are borne at intervals on the stem of the inflorescence. In the axils of the upper bracts are branches, which in turn branch. If carefully looked into, the main and lateral branches will be found to end in flowers, the inflorescence being, as in the White Meadow Saxifrage, a cymose one.

The small flowers consist of the same parts as do those of

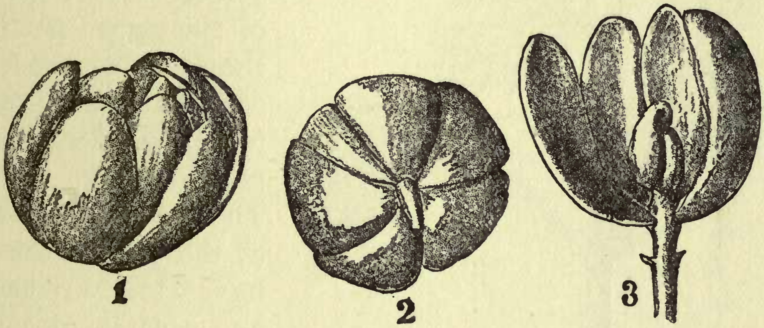


FIG. 89.—Bulbils of the White Meadow Saxifrage. (After Schumann.)

S. granulata described above, and the parts are arranged in the same way. The petals are, however, small and of a pinkish white colour, marked with a number of pink spots; each has a larger yellow spot near the base. The pistil, which is not so deeply sunk in the floral receptacle, has a pink colour and it and the anthers add to the colour of the little flower. This is visited by small flies and, since the stamens have shed their pollen before the stigmas mature, cross-pollination is readily effected. The branches of the London Pride form short runners and readily take root, so that the plant extends by vegetative means and forms large patches. It is of interest to compare this less specialised means of vegetative reproduction with the formation of bulbils in the White Meadow Saxifrage.

HERB-ROBERT (*Geranium Robertianum*, L.).

There are many points of interest in the Common Wild Geranium or Herb-Robert that will repay careful study. This plant can be found in any hedgerow, and flowers throughout the whole summer. It is an annual, and grows rather loosely attached to the soil by a main root bearing lateral branches. At the base of the main stem are a number of closely crowded foliage-leaves with long stalks, and from the axils of some of these, branches resembling the main shoot may spring. The internodes of the upper portion of the shoot become longer, while at each of the rather swollen nodes a pair of leaves is borne. The stem and leaf-stalks at the base of the plant have a bright red colour, and this is also found at the nodes and the bases of the leaf-stalks in the upper part of the shoot. The surface of these parts is clothed with projecting whitish hairs. The plant has a peculiar and rather unpleasant odour, and is noticeably brittle, the leaves and stems separating readily at the nodes. The general appearance of a shoot bearing leaves, flowers, and fruits is represented in Fig. 90.

FIG. 90.—Flowering shoot of the Herb-Robert. (After Baillon.)

Each leaf has a pair of small stipules, which remain on the stem when the leaf breaks away. These are green and pointed, and hairy on their lower surface and edges. The almost cylindrical leaf-stalk shows hardly any distinction of upper and lower surface. It tapers gradually till the compound blade, consisting of three

main leaflets each of which is deeply divided, is reached. The leaf-blade is softly hairy, especially above where it is of a deeper green tint. The leaves are all similar, though in the flowering region the blades are smaller and the stalks are very short.

The main branch terminates in an inflorescence, and lateral branches from the axils of its leaves end similarly and continue the branching of the plant. The ultimate region of each shoot bearing the flowers always consists of a thin cylindrical stem bearing a pair of leaves reduced to their minute stipules. This ends in the first flower, and in the axil of one of the reduced bracts is a second flower opening later than the first one. The small inflorescences have thus regularly two flowers (Fig. 90).

The calyx of the flower consists of five sepals, which are not joined together but stand so close and erect as to practically form a tube enclosing the base of the flower. Each sepal has well marked green veins bearing glandular hairs, and ends in a green point tipped with red. Within the sepals, and alternating with them, are the five petals forming the corolla. These are also free from one another, and each consists of a stalk-like portion standing erect within the calyx, and a wider pink and red-coloured part, which spreads out almost at right angles to the lower portion and forms the conspicuous corolla. Each petal shows three whitish streaks converging towards the centre of the flower.

Projecting from this we find the stamens and stigma. The stamens are ten in number, and form two whorls of five. Each has a colourless stalk, which is flattened out at the base, but is slender and cylindrical above, where it bears a reddish anther. This on opening liberates the bright yellow pollen. The pistil, which is clearly seen on removing the stamens, consists of the pale green, five-lobed ovary, the style, which tapers upwards, and the reddish stigma consisting of five diverging lobes. There are five carpels composing the pistil, and in each of the five chambers of the ovary is a single ovule.

The flowers of the Herb-Robert are visited by insects, and are usually cross-pollinated by their assistance. Nectar is secreted by the outer sides of five of the stamens close to their attachment, and accumulates in the bases of the sepals. The five outer stamens open first, and when they are shedding their pollen the style is still

short, and the lobes of the stigma closed together. By the time the five inner stamens are shedding their pollen the style has lengthened and the stigmatic lobes are expanded at a somewhat higher level than the anthers. The flower has thus an earlier stage in which pollen is being shed, but fertilisation is impossible, and a later stage in which it is capable both of giving and receiving pollen. Even in this stage, cross-pollination is, however, more likely to occur than self-pollination, owing to the position of the stigmas above the anthers.

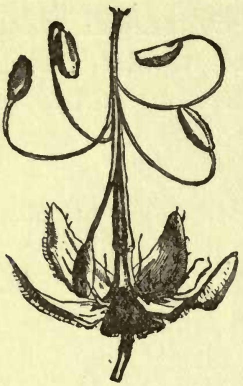


FIG. 91.—Fruit of the Herb-Robert, opening to eject the seed. (After Baillon.)

The fruit is of interest on account of the way in which the seeds are scattered to a distance from the plant. After pollination the ovary with its five lobes enlarges, and the lower portion of the style also increases in length, and thickens. At the upper end it bears the remainder of the style and the withered stigma. The base of the fruit is surrounded by the sepals, but the stamens and petals have fallen off. The fruit is dry when ripe, and opens by the five outer portions of the carpels separating from below upwards from a central column (Fig. 91), and forcibly scattering the seed to some little distance. In the Herb-Robert the seed, when detached, is enclosed by the lower part of the wall of the ovary, while in some other species of *Geranium* the seeds are ejected separately, and the wall of the fruit remains attached to the central column.

THE SPOTTED ORCHIS (*Orchis maculata*, L.).

The Early Spotted Orchis is one of the commonest of our British Orchids, and can be found in flower, often in large numbers, in damp grassy spots and on heaths and moors, in May and June. Its study will serve admirably as an introduction to the wonderful adaptations which the Orchids show both in their vegetative organs and their flowers. It must be remembered, however, that these adaptations are very various, and require special study in

each case. The description of *Orchis maculata* applies in general to a number of our native Orchids.

For the study of the Spotted Orchis care must be taken to obtain complete specimens. The plant must be very carefully dug up, and the underground parts freed from the surrounding soil. When this is done the plant will be seen to consist of two swollen, tuberous structures and a number of ordinary roots below ground, and of a single erect stem bearing foliage-leaves below and ending in the inflorescence of crowded, whitish-lilac flowers. Smaller specimens which do not flower should be studied as well as the larger plants, and observation should be carried on throughout the season, so that the annual history can be followed.

The two tubers at the base of the plant present important points of difference (Fig. 92, 1). They are thick swollen structures divided at the free end in a palmate fashion ; each lobe continues as a cylindrical root. The tuber is evidently a peculiarly modified root or group of roots. It is modified for the storage of reserve food material. One of the two tubers stands immediately at the base of the leafy shoot of the plant, while the other appears to be attached to the side of the lowest part of the shoot. The latter tuber is plump, firm, and of a white colour. Above it is a bud to which the tuber is related. The bud which once stood above the other tuber, which is now brownish and soft, has grown into the leafy shoot bearing the inflorescence. The growth took place at the expense of the material stored in the old tuber, which is now practically emptied of its contents. From the stem immediately above the tuber a number of long, cylindrical, unbranched roots have developed, and above this the stem bears two or three scale-leaves. These are hidden below the soil, and are brown or colourless. The bud mentioned above as connected with the new tuber was borne in the axil of the lowest or second lowest of these scales, but has enlarged and burst through the base of the scale-leaf ; it is thus visible without any dissection. The new root-tuber springs from the base of this bud.

We can now form a clear idea of how the growth of this Orchid continues from season to season. When the plant dies down in the autumn all that is left in the soil is a tuber, stored with food

material and bearing a bud. In the spring the bud grows into a foliage and flowering shoot, which forms a few absorbent roots

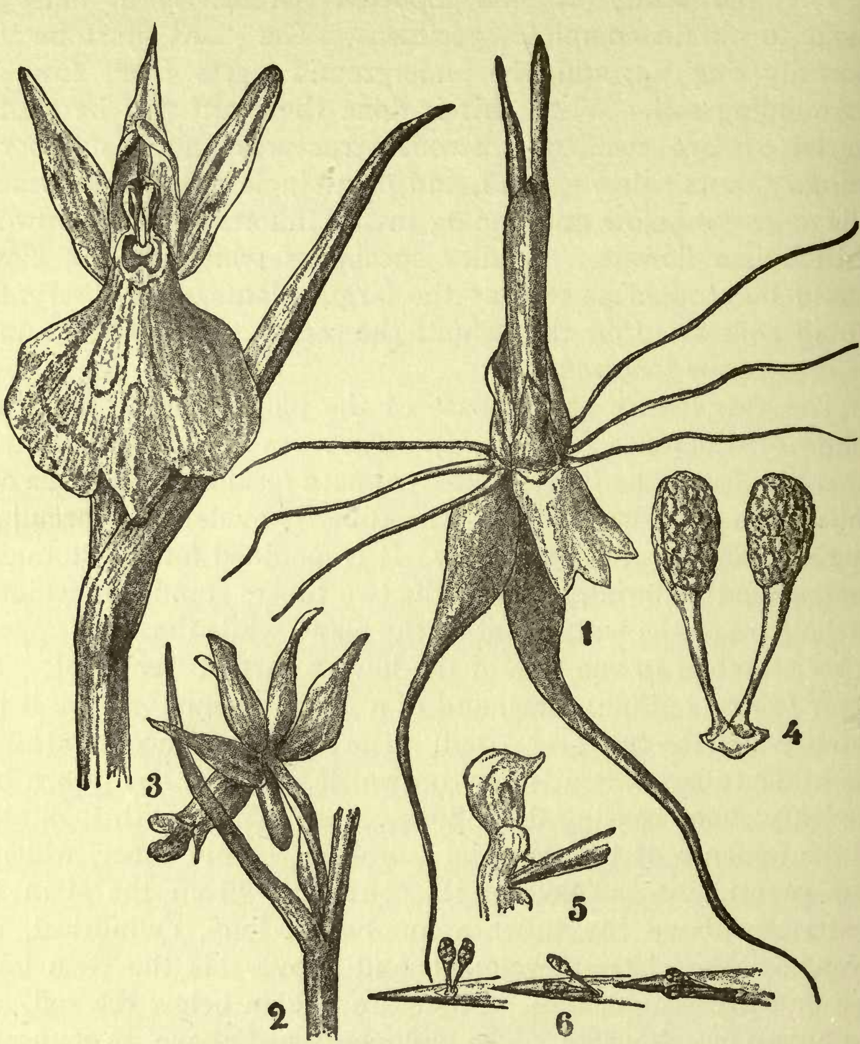


FIG. 92.—Spotted Orchis. 1, Complete plant early in the season showing the origin of the new tuber; 2, portion of stem of inflorescence with a bract in the axil of which a flower, seen from behind, stands; 3, flower seen from in front; 4, the pair of pollinia, magnified; 5, point of a pencil depressing the rostellum, and coming in contact with the sticky discs; 6, movements of the pollinia, removed on the pencil. (After Schumann.)

at the base of the stem. Preparations are at once begun for the continuance of the plant in the following season by the enlarge-

ment of one of the lowest lateral buds and the development of a root-tuber on this. During the season this new tuber enlarges, and is stored with food materials manufactured by the foliage-leaves, and it, with the related bud, remains to carry on the growth of the plant in the following spring.

The unbranched stem bears, as mentioned above, several scale-leaves at its base, and above this a number of green foliage-leaves. Each leaf is distant from the preceding one by about one-third of the circumference of the stem, and on passing from the lowest scale-leaves, which are merely colourless sheaths, to the upper foliage-leaves a gradual increase in size of the leaf-blade is apparent. The sheathing base of each of the larger foliage-leaves completely embraces the stem for some distance above the node. The narrow leaf-blade is not flattened, but remains folded at the midrib, so as to show a chanelled upper surface. The colour is deep green marked with irregular blackish spots on the upper surface, while below it is of a uniform paler tint and shows clearly the parallel course of all the main veins. The spotting of the leaf, to which the English name refers, varies in degree in different specimens, and may be almost wanting.

Above the largest foliage-leaves we find a gradual diminution in size of the leaf-blade, which becomes more pointed and has a shorter leaf-sheath, until we come to the bracts of the inflorescence. These are evidently reduced leaves with a small, pointed leaf-blade and practically no leaf-sheath. In the axil of each bract is a single flower, and, since the internodes in this region are short, the shoot of the Orchid ends as a dense spike of flowers. At first sight each flower appears to have a thick green stalk marked by spirally running ridges, but further examination will show that this is really the inferior ovary, and that the flower has no stalk.

If a fully opened flower is removed and looked at from the front (Fig. 92, 3) it is at once clear that only the plane of division passing from front to back would divide it into two similar halves ; it is an irregular flower. Seated at the end of the stalk-like ovary are six perianth-leaves, which are all delicate and petal-like in texture, and of a whitish colour marked with streaks or spots of lilac. The perianth-leaves form two whorls of three.

As looked at from in front one of the three leaves of the outer whorl stands in the middle line behind, while the other two stand to either side of the flower. The three leaves of the inner whorl alternate with those of the outer whorl. Two, standing towards the back of the flower, are small and narrow, like the leaves of the outer whorl, and their tips bend inwards so as to meet. They form, together with one of the leaves of the outer whorl, a hood-like structure overarching and protecting the parts within. The third leaf of the inner whorl is very different in shape and size to the others. It forms a wide apron-shaped lip to the front of the flower (Fig. 92, 3), and is continued back as a tubular spur (Fig. 92, 2). It is called the lip or labellum.

The parts of the flower within the perianth may be seen on looking into the flower (Fig. 92, 3), or by removing all the perianth-leaves from a flower (Fig. 92, 5). Looking into the opening above the labellum which leads into the spur, the back wall of the opening appears to be formed by two dull white surfaces, which are continuous across the middle line and have their edges defined by a coloured line. These areas are the two receptive lobes of the stigma. Immediately above the stigma is the single stamen, which is not very like in appearance to the stamens of most flowers. The two anther lobes are shaped like Indian clubs with their dilated ends pointing upwards (Fig. 92, 3). They lie parallel to one another, and their narrower ends come in contact with a small globular structure overhanging the entrance to the spur. This is known as the *rostellum,* and corresponds to the third lobe of the stigma specially modified to perform a particular function.

The anther lobes have a purple colour, but when opened by a longitudinal slit the greenish mass of pollen is visible in each. This is not as usual loose and powdery, but all the pollen of each anther lobe is joined together to form a club-shaped mass or *pollinium.* The lower part of this forms a tapering stalk which is connected to the membrane forming the back of the rostellum. The rostellum when mature consists of a thin membranous wall enclosing a sticky substance, which has resulted from the breaking down of the central tissue. The sticky material has collected in two little hemispherical masses against the parts of the mem-

brane to which the stalks of the pollinia join on the outside. These two circular discs of the membranous wall of the rostellum are defined by a split which forms in the membrane when the flower is mature. Anything that presses against the front of the rostellum will press down that part of the membrane and expose the two sticky discs. These will adhere to the object touching them, and carry away with them the pollinia from the anther lobes.

Touching the front of the rostellum with the point of a pencil will show the general structure and remove one or both of the club-shaped pollinia (Fig. 92, 4, 6), which can then be examined with a lens. In each we distinguish the little patch of membrane at the base, the stalk, and the mass of pollen grains held together in packets by sticky threads.

To either side of the single fertile stamen a small whitish projection will be seen on careful inspection (Fig. 92, 5). Each of these is the last remains of a stamen, and they mark the position of two other stamens in the flower, though these no longer form pollen. If (having recognised the single stamen, the two rudimentary stamens and the stigma, one lobe of which forms the rostellum) the relative positions of these parts are considered in a flower from which all the perianth-leaves have been removed, they will be found to be joined together. The stamens appear to be joined to the back of the style (Fig. 92, 5), or more correctly the stamens and the stigma are carried up together, forming a region known as the *column*.

If we now return to the intact flower we shall be in a position to understand how the various parts of this complicated mechanism work together in pollination. In the first place, it is obvious that if a flower is left undisturbed there will be no likelihood of self-fertilisation taking place. The flower is completely dependent on insect visits for pollination. Bees and flies visit the flower for a sweet juice, which is not as in most Orchids accumulated in the spur, but is obtained by probing the soft walls of this. The insect alights on the labellum, and in inserting its head into the opening of the tube comes in contact with the rostellum. It depresses the lower part of this, and so exposes the viscid discs. These adhere to the head or proboscis of the insect,

and the pollinia are removed when the insect withdraws its head.

The method of removal of the pollinia can be studied by inserting a sharply pointed pencil into the spur (Fig. 92, 6). This reveals a further important feature in the behaviour of the pollinia. As the viscid disc dries it contracts unequally, and as a result of this the pollinia are bent forwards, and at the same time diverge slightly from one another. The importance of this movement will be evident if the position of the stigmatic surface is taken into account. If it did not occur, the insect on visiting another flower would tend simply to replace the pollinia in the cavities of the anther lobes. Owing to the movement, however, the tips of the pollinia now come in contact with the stigmatic surfaces situated below and to either side of the rostellum. This surface is very sticky, and it will be found that when a pollinium is brought in contact with it and then pulled away a greenish stain remains on the stigma. The latter has removed a number of pollen grains, but has not taken the whole pollinium. One pollinium thus serves to pollinate a number of flowers. The whole mechanism, on the one hand, makes self-fertilisation impossible, and on the other, is beautifully adapted to ensure cross-pollination as the insects pass from flower to flower.

So far we have considered the flower in the position it occupies on the spike when fully open. If, however, the buds near to the tip of the inflorescence be looked at, the labellum will be found to stand at the back of the flower. This is its proper position, and comparison with flowers lower down will show that it is only brought into the anterior position occupied in the open flower by a twist of the ovary. This explains the spiral course of the ridges on the latter. The inferior ovary is composed of three carpels and encloses a single cavity. The minute ovules stand in three rows, corresponding to the lines of junction of the carpels.

Later in the season inflorescences will be found bearing fruits. The perianth has withered and fallen off. The ovary has enlarged into the fruit, and the ovules have developed into the very numerous and small seeds. The dry fruit opens when ripe by longitudinal splits, and the seeds escape and are readily carried by the wind. The young plant developed from such a minute seed

cannot grow at once into a plant like the parent. It is some years before it is able to flower, and during this time it increases in size and forms a larger tuber each year. The young plants can be found in situations in which the plant grows abundantly, and a series of different ages may be collected and will make a portion at least of the life-history clear.

The account given above will serve as a guide to the study of several British Orchids with root-tubers. In other British species we find an ordinary root-system. The methods of pollination are described in the earlier chapters of Darwin's *Fertilisation of Orchids*, and the more advanced student should consult this work.

THE GREATER PLANTAIN (*Plantago major*, L.) AND THE RIBWORT PLANTAIN (*Plantago lanceolata*, L.).

The two kinds of Plantain to be described here are among our commonest weeds. They can be found by every roadside in waste places and in grass land. If not known by name they will be identified by two uses to which their inflorescences are commonly put. Those of the Greater Plantain when in fruit are gathered for canaries, while every child knows the black, long-stalked inflorescences of the Ribwort Plantain which are used in the game of "Soldiers." Both plants are perennial and can grow on very bare and unpromising spots, so that they compete successfully with other plants in the colonisation of such places.

The Greater Plantain (*P. major*) (Fig. 93), as can be seen in a specimen that has been carefully dug up, has a short, swollen, main stem which continues its growth year after year without forming any vegetative branches. A number of sparingly branched roots fix the almost globular stem in the soil; no main or tap-root can be distinguished. Toward the upper part of the short stem are the crowded leaves, which spread out on all sides and often have their large blades more or less closely applied to the soil. Each leaf has a wide sheathing base, which narrows gradually into the leaf-stalk. This is strongly concave above, and at its upper end expands rather suddenly into the

broad, oval leaf-blade. The course of the veins in the leaf-blade is clearly seen on looking at the lower surface. Three to seven main veins enter from the leaf-stalk and run almost parallel. Those near the middle of the leaf reach nearly to the tip, while

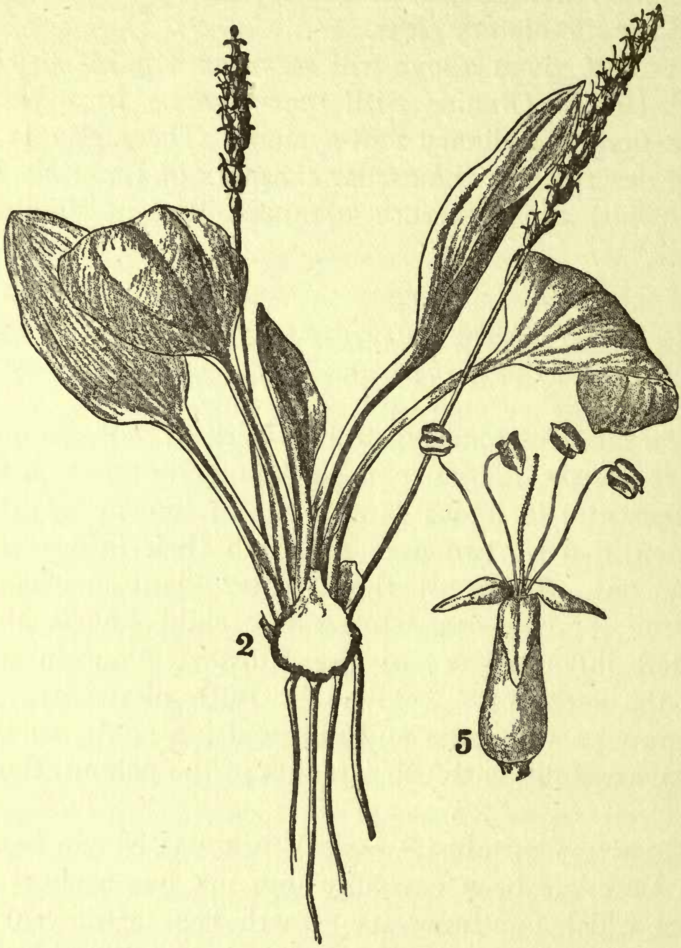


FIG. 93.—Greater Plantain. 2, Plant bearing inflorescences cut in half; 5, single flower. (After Schumann.)

the lateral ones die out before this is reached. Between the main veins is a network of fine branches.

Since vegetative branches are not produced even old plants show an unbranched stem. The axillary buds mostly develop into inflorescences, the existence of which is limited since they

wither after the fruits have ripened. The inflorescences destined to grow up in the next summer may be found in the autumn as small pointed bodies protected by a felt of white, silky hairs, and standing in the axils of the foliage-leaves.

The inflorescence grows into a long, erect spike with a bare stalk below, while the numerous small flowers are crowded on the upper part. Each flower stands in the axil of a small, green, scale-like bract. The flower (Fig. 93, 5) though of small size has calyx, corolla, stamens, and pistil. The calyx is composed of four separate greenish sepals. Within this we find a corolla composed of four petals united together in the lower part. The corolla is also greenish, and is of more delicate texture. As Fig. 93, 5, shows, the free upper parts of the petals expand almost at right angles to the lower tubular part of the corolla. The four stamens alternate with the petals and are attached to the inner surface of the corolla tube. The long, slender filaments project freely from this, and carry the anthers clear of the other parts of the flower. In the centre of the flower the small greenish ovary will be found by carefully slitting up the corolla with the point of the knife. It is usually two or three chambered, and the few ovules are attached to a thick, central placenta, between which and the wall the thin septa extend. The ovary is surmounted by a single style continuing into a long stigma, the surface of which is clothed with papillæ.

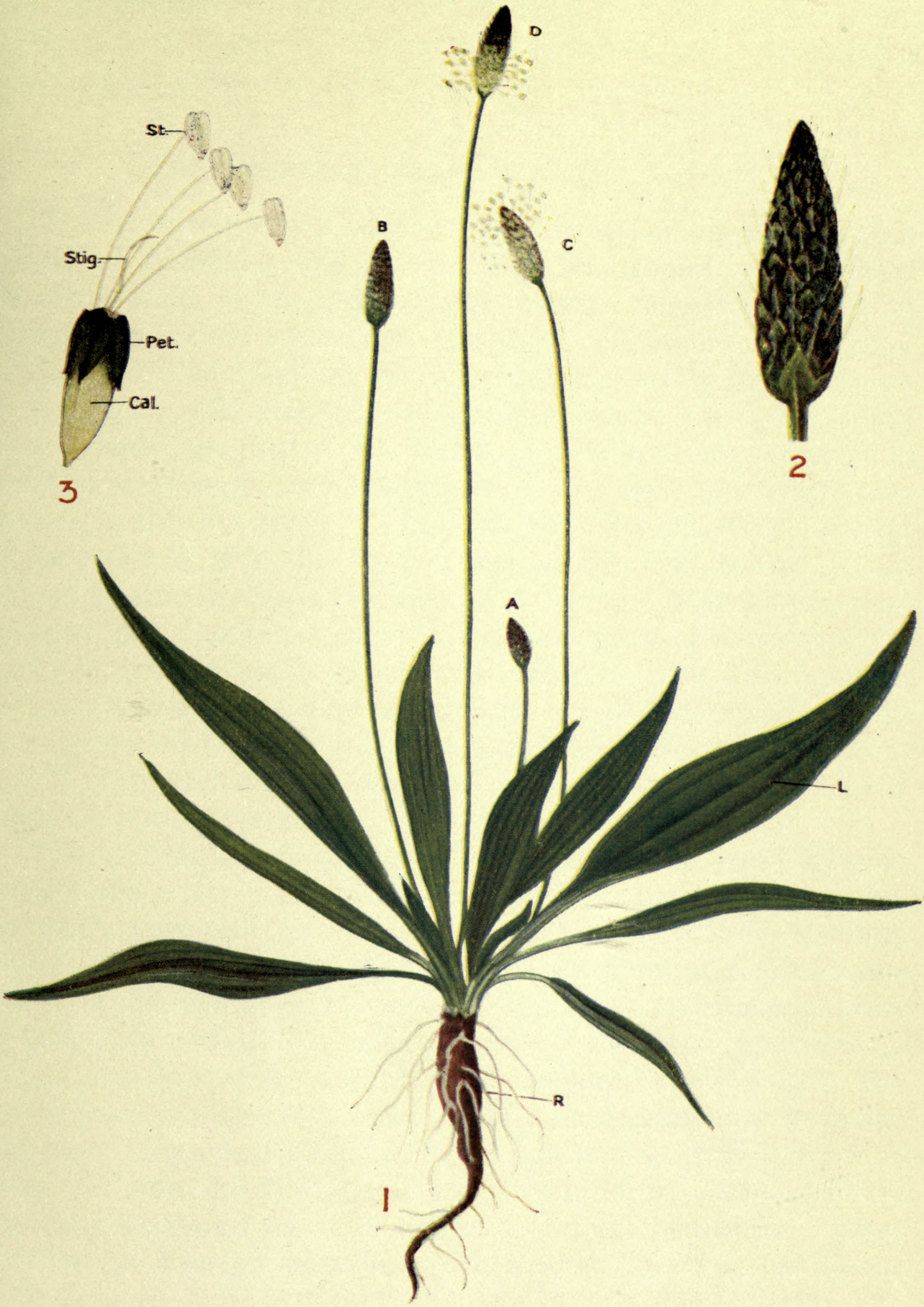
The flowers of the Greater Plantain, though individually inconspicuous, are prominent by reason of the stamens projecting from the open flowers massed together on the inflorescence. The anthers before dehiscence have a purplish colour, and when they open liberate dusty pollen, which escapes readily and is carried by the wind. The large and hairy stigma is well suited to catch such wind-borne pollen grains, and the whole aspect of the flower suggests its suitability for wind-pollination. It is doubtless often pollinated in this way, but, although the flowers contain no nectar, they are sometimes visited by bees. These come to collect pollen, which they have to moisten with saliva in order to carry away.

These insect visitors may carry pollen from one flower to another, and we may look upon the flower as in some degree intermediate between a wind-pollinated and an insect-pollinated

one. Its general features are, however, more those of a wind-pollinated flower. Since the stigma is usually capable of receiving pollen at the time that this is being shed by the stamens of the same flower, self-pollination is not prevented as it is in the Ribwort Plantain.

The small, dry fruit developed from the ovary after fertilisation is of interest owing to the way in which it opens to liberate the seeds. A circular split forms about one-third way up the fruit, and the upper portion separates as a lid from the cup-shaped lower part. Some of the seeds fall off with the lid, while others remain for a time in the lower portion.

The Ribwort Plantain (*Plantago lanceolata*) is similar in the main features of growth and floral structure to the Greater Plantain, but differs in details. It is represented in the accompanying plate. There is a long, stout, tapering tap-root growing vertically into the soil, and giving off thin lateral branches. The stout main stem has no vegetative branches. It bears below the remains of the leaves of former seasons, and farther up the present foliage-leaves. The leaf-blade is narrower than in the Greater Plantain, and the almost parallel main veins project very strongly on the lower surface. The inflorescences, which develop from the axillary buds, have a long, leafless, strongly ribbed stalk, six inches to a foot in length, and at the summit a short spike of flowers. The bracts are greenish, edged and tipped with brown, and each has a single flower in its axil. The structure of the flower is similar to that of the Greater Plantain. The way in which the flowers open presents an important difference, however. The opening begins with the flowers at the base of the spike, and proceeds towards the tip, and the different stages in the flowering can be made out in a single inflorescence, though better if a number of different ages are gathered and compared. It will be found that the stigma matures first, projecting from the partly closed flower. Only after the stigma has withered does the flower open fully, and the stamens project and liberate their dusty pollen. Self-fertilisation is thus prevented, and the flowers are usually cross-pollinated by means of the wind. Inflorescences of various ages are represented in the plate. The arrangements for preventing self-pollination and for facilitating



RIBWORT PLANTAIN (*Plantago lanceolata, L.*).

I. Complete plant. R. Root. L. Leaf. A, B, C, D. Inflorescences of successive ages.

II. Inflorescence in an early stage showing the stigmas projecting from the closed flowers which stand in the axils of the bracts.

III. Single flower, fully opened. Cal. Calyx. Pet. Petals. St. Stamens. Stig. Stigma.

the conveyance of pollen by the wind may be instructively compared with those in the Field Woodrush (p. 52), an unrelated plant which grows in similar situations.

THE CHARLOCK (*Brassica sinapis*, Visiani).

The Charlock is one of the commonest and most abundant weeds of cornfields and other cultivated ground. From May onwards whole fields may appear bright yellow owing to its flowers, and even when less abundant specimens can readily be found. The plant is an annual one, growing up from seed in the spring, and reaching its full size, which varies according to the conditions from a few inches in ill-nourished specimens to two feet in strong, branched examples. The plant bears numerous flowers, and fruits freely. The seeds shed from the fruits remain in the soil and give rise to the crop of the next spring. Such annual plants, in which the individuals do not persist from year to year, are dependent on an abundant production of seed for their success in competition with others. They are not well suited to take possession of ground already occupied with a close growth of plants, but find suitable conditions in the bare soil of cultivated fields. Many of the weeds of our gardens and crops are annual plants.

The Charlock is best studied in a fully grown plant bearing flowers and fruits. It has a stout tapering tap-root, which grows vertically down into the soil and gives off slender, branched, lateral roots. The main stem of the plant bears a number of fairly large leaves, which are situated singly at the nodes and are separated by long internodes. The stem is green, cylindrical, and slightly ribbed, and its surface bears short, stiff, white, bristly hairs. The leaves have a short, wide stalk, hardly distinguishable from the leaf-base, and a leaf-blade, which is either oval with a toothed margin or more deeply divided into pinnate lobes. Stiff hairs are sparingly scattered on both surfaces and at the margin. After bearing the two seed-leaves, which may be found at the lowest node even in mature plants, and four or five foliage-leaves, the main shoot of the plant continues as an inflorescence. In strong plants the buds in the axils of several of the foliage-leaves develop

into lateral shoots, which bear a few leaves and end in inflorescences; the lateral shoots may in turn branch and bear inflorescences.

The inflorescence consists of the main axis of the shoot bearing laterally placed flowers. It continues to grow for a long time, producing a succession of flowers, and in old plants buds may still be found near the tip of an inflorescence that lower down bears almost ripe fruits. Each flower corresponds to a lateral branch, but, as is the rule in the group to which the Charlock and the Lady's Smock belong, the bracts are wanting below the flowers.

FIG. 94.—Shoot of the Charlock bearing flowers and fruits. (After Baillon.)

The flower has a well-marked green stalk. There are four, pale green sepals, which completely cover in all the other parts in the bud. The sepals are in two pairs, those of the outer pair being flatter than those of the inner pair. The two pairs alternate, the sepals of the outer pair standing front and back in the middle line. The corolla is composed of four petals inserted at the same level on the receptacle of the flower, and alternating with the four sepals. Each petal consists of a narrow, erect, flat, stalk-like part of a greenish colour, which widens out into the oval yellow upper portion. The four yellow expansions are bent at right angles to their stalks, and diverge in the form of a cross. Within the corolla, as is best seen on removing the sepals and petals from a flower, are six stamens. These stand at two levels on the receptacle. To either side of the flower, and at the lower level on the receptacle, is a single stamen which is shorter than the stamens of the inner whorl. These are four in number, one pair standing to the front and the other to the back in the flower as it stands on the main stem. The filaments bear fairly large anthers which on opening liberate yellow pollen. In the centre of the flower is the pistil. This is

formed of two carpels, and consists of a pale green, cylindrical ovary clothed with downwardly pointing hairs, an ill-defined style, and a stigma composed of two yellowish lobes standing front and back in the flower. The structure of the ovary will be best considered along with that of the fruit.

The flowers of the Charlock are conspicuous, not merely on account of their individual size, but by their aggregation in the inflorescence. They are visited by numerous insects which come partly to collect or feed off the pollen, but also in search of nectar. This is secreted in abundance by the nectaries, which are very easily seen in a flower from which the calyx and corolla have been removed. One large green nectary stands just within the insertion of each short stamen, while a smaller gland is situated to the outside of each pair of long stamens. Owing to the way in which the sepals diverge the honey could be reached from the outside of the flower, but insects, as a rule, approach in the more usual way, and, alighting on the petals, pass their tongues down the centre of the flower. All the anthers at first face inwards towards the centre of the flower, and those of the two short stamens remain in this position. Since they stand at a lower level than the stigma, there is little likelihood of the pollen effecting self-pollination. The anthers of the two pairs of long stamens are situated at a slightly higher level than the stigma. As the flower opens they make a more or less complete half-turn, and so come to face outwards. An insect sucking the honey at the base of the short stamens will have one side of its head against the stigma while the other is being dusted with pollen. When getting honey from the nectary at the base of the long stamens it will be dusted with pollen from their anthers, but will not touch the stigma. Insects passing from flower to flower will thus effect cross-pollination. Should this not take place, after the flower has been open for some days the anthers of the longer stamens bend backwards, and the stigma as it grows up comes in contact with them and is self-pollinated.

The fruit (Fig. 95) is simply the greatly enlarged pistil after the sepals, petals, and stamens have fallen away. It is a long, green, pod-like structure with a flattened beak, at the summit of which is the remains of the stigma. There are no seeds in the beak-

like part. The two carpels forming the pistil are joined by their edges to enclose a single cavity, and the ovules are attached along the lines of junction of the carpels. Ingrowths from these lines of junction form a partition, which divides the cavity of the ovary into two. The fruit shows the result of the further development of all these parts. It is smooth, or bears stiff hairs like those on the stem. Looked at from the outside, it is readily seen to be formed of two carpels. The curved part of each of these shows three veins, while the lines of junction are of a darker green. If one of the valves be split away from the rest of the fruit the seeds, which have developed from the ovules as a result of pollination, will be seen. They are rather large rounded bodies, which are attached by slender stalks to the wall of the ovary. The enlarging seeds have pressed the partition aside, and since some are on the near side of the septum and some on the other half of the fruit, about half the seeds appear covered by the thin partition. If both valves are removed, which happens naturally when the ripe fruit opens (Fig. 95, B), they leave the partition stretched between the two strips of ovary wall from which the seeds sprang.

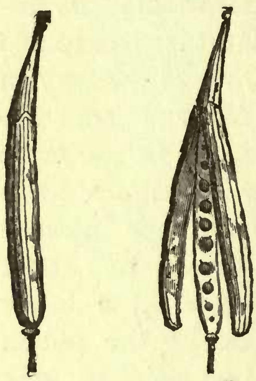


FIG. 95.—Fruit of the Charlock, showing in B the mode of dehiscence. (After Baillon.)

The seeds then fall to the ground. They are relatively large and have no special method of being scattered to a distance. Each round, smooth seed consists of the seed-coat enclosing the embryo plant. The food material is stored in the thick seed-leaves, which on germination expand as a pair of small, notched, green leaves. These can sometimes be seen at the base of the shoot even of well grown plants.

THE SHEPHERD'S PURSE (*Capsella bursa-pastoris*, Moench).

The Shepherd's Purse belongs to the same natural family of plants as the Charlock and the Lady's Smock. It is, however, such a common weed, and can be found in flower and fruit from spring to autumn, that a brief account of its main features will be

useful. Specimens can readily be obtained from gardens, waste ground, by the side of walls, or round farm-steadings, for the Shepherd's Purse accompanies human activity like the Sparrow. It gets its English name from the shape of the flattened and heart-shaped fruits (Figs. 96, 97).

The plants vary greatly in size, probably owing to the conditions of their life. They grow from the seed, flower and fruit and then die, the usual life of a plant being under a year, though individuals may persist over the winter. The well-marked whitish tap-root extends vertically into the soil, giving off branched lateral roots. At the base of the shoot is a rosette of long-stalked leaves, and above this the stem has elongated internodes and bears a few foliage-leaves before passing into the long inflorescence. Larger plants branch from the axils of the leaves. Each branch bears a few foliage-leaves and ends in an inflorescence. The general appearance of the plant will be gathered from Fig. 96.

FIG. 96.—A small complete plant of the Shepherd's Purse. (After Baillon.)

Both the stem and leaves bear short, pointed white hairs. The leaves of the basal rosette have an ill-defined leaf-stalk. In the upper leaves on the main shoot the stalk is less marked, while the leaves on the lateral shoots may be described as without stalks. The leaf-blade has a strong midrib and, though often deeply divided, is not compound or branched. All intermediate forms can be found between leaves with the margin merely toothed and those in which the divisions reach almost to the midrib.

The inflorescence, as in the Charlock, has no bracts beneath the flowers. Growth proceeds at the end of the shoot throughout the season, so that buds and open flowers will be found near the tip, while fruits of all ages are present lower down. The flowers have fairly long stalks and, though much smaller, are composed of

the same parts as in the Charlock or Lady's Smock. It is therefore unnecessary to describe the arrangement of the parts in detail. There are two pairs of sepals, four small white petals, two short stamens and two pairs of longer stamens, and the pistil. Since the anthers of the longer stamens stand at about the level of the stigma, pollen will easily get upon this, and the flower be self-pollinated. Nectar is, however, secreted by a pair of nectaries at the base of each of the shorter stamens and, when the flower is visited by insects, cross-pollination may be effected. The flower is thus of interest in being constructed on the plan of an insect-pollinated flower, but relatively reduced and inconspicuous and mainly dependent on self-pollination.

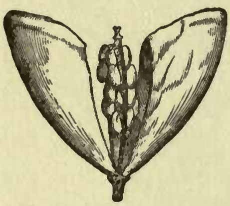


FIG. 97.—Fruit of the Shepherd's Purse opening to liberate the seeds. (After Baillon.)

The pistil, composed of two carpels, is short and flattened, and extended in the plane of the shorter stamens in the flower. It consists of the ovary, a short style, and a rough two-lobed stigma. The fruit (Fig. 97) is derived from the pistil, the other parts of the flower falling away. It is flattened, and widens gradually from below upwards. At the broad upper end is a depression, from the middle of which the remains of the stigma projects. The fruit consists of two chambers separated by a partition which lies in the plane at right angles to that of the flattened pod. The greater part of each of the carpels can be pulled away, leaving the seeds attached to the margin of the septum. What can be done artificially happens naturally when the fruit is mature (Fig. 97), and in this way the seeds become free. In its construction the pistil and fruit of the Shepherd's Purse thus resembles that of the Charlock (p. 212), although it is short and broad instead of elongated. Owing to the certainty of pollination, every flower produces a fruit, and the large number of seeds produced explains the abundance of the plant in suitable situations.

THE COMMON AVENS (*Geum urbanum*, L.).

The Common Avens is a perennial herb growing by roadsides and often in the shade of woods, and flowering from June to

August. Its general appearance is shown in the accompanying plate. The young plant has a main root, but roots also spring from the stem and in older plants only these may be found. The short thick stem grows on year after year, producing a number of long-stalked foliage-leaves each year. The older parts of the stems are clothed with the withered brown bases of the leaves of former seasons. According to its size, the plant may bear one or several erect shoots with a number of foliage-leaves at the lower nodes and flowers above. These shoots stand in the axils of leaves of the preceding season; usually only the withered base of the leaf can be seen.

Each of the large leaves has a wide sheathing base of a reddish colour. This is thick in the middle, and thins out into margins fringed by long hairs. To the sides of the leaf-base just where it passes gradually into the leaf-stalk the small green tips of the stipules can usually be made out. The leaf-stalk is chanelled above, convex below, and like the rest of the plant is clothed with short hairs. The leaf-stalk ends in a large, thin, three-lobed blade, and the leaf at first sight appears a simple one. But below this we find one or two pairs of small leaflets, so that it is clear that we have to do with a pinnate leaf, the tip of which is greatly developed while the lateral pinnæ are small. The margins of the pinnæ and terminal blade are cut into rather wide teeth, each ending in a sharp point. The main veins project on the lower side of the leaf-blade, which is hairy on both surfaces.

The erect shoots have a stout green stem, marked with projecting ribs extending down from the sides of the leaf-bases. The internodes are elongated and each node bears a leaf, which consists of a leaf-base with a large green leafy stipule to each side, a longer or shorter leaf-stalk, and a leaf-blade consisting of a terminal leaflet and a pair of lateral leaflets. The axillary buds of these lower leaves may give rise to lateral flowering shoots. Higher up on the main shoot the leaves become still simpler in form, and consist of the pair of leafy stipules and a short stalk expanding into the single terminal leaflet.

The main axis of the inflorescence ends in a flower which is the first to open, and the lateral shoots similarly terminate in flowers. A short distance below the flower a pair of small bracts standing

almost opposite to one another are borne, and flowers are produced in the axils of these.

The flower has a cylindrical, green, hairy flower-stalk. At the base of the flower where it passes into the floral receptacle this widens out distinctly. On cutting a flower in half it will be seen clearly that the receptacle forms a plate-like expansion similar to that in the Strawberry flower, but more distinct. Around the margin of this stand the five triangular green sepals, and below and between these (as on the Strawberry) are five, smaller, pointed, green structures, which here also may be explained as derived from the stipules of the sepals.

The petals are also borne on the margin of the flattened receptacle, and alternate with the sepals. Each is bright yellow, has a rounded outline, and is attached by a narrow base. Within the corolla we come to numerous stamens inserted on the upper surface of the receptacle near its edge. Each has a greenish stalk and a small bright yellow anther. Centrally, on a rounded projection of the summit of the receptacle, are the numerous small carpels. The insertion of each carpel is distinct from that of the others, and its swollen basal part forms a little green hairy ovary, while the upper part forms the style and stigma. There is a little kink or bend in the upper part of the style, while the portion above this bears the stigmatic surface. Each ovary encloses a single ovule, but the structure of the ovary will be best made out after it has enlarged in the fruit.

The fruit develops from the whole group of carpels after pollination. The petals fall away, the sepals bend back round the flower-stalk, while the withered remains of the stamens are visible beneath the enlarged end of the receptacle bearing the globular group of carpels. Each of these now forms a fruitlet. The flattened green portion developed from the ovary can now be opened with the point of the knife, and will be found to contain a single developing seed. The style has persisted and elongated ; it bears near the upper end the little bend or hook already referred to, and beyond this the remains of the stigma. When mature the fruitlets are readily detached from the receptacle. The hooked style assists in their dispersion. It would catch readily in the fur of an animal, as it will be found to do in the cloth of a coat-

THE COMMON AVENS (*Geum urbanum, L.*).

sleeve, and the fruitlet may thus be carried to a distance before it drops on the soil. Since the fruitlet contains only one seed, it does not open, and the seed remains protected by the walls of the fruit until germination. It is very interesting to contrast the mode of dispersal of the fruitlets in the Avens with what occurs in the fruit of the Strawberry, which is developed from a very similar pistil.

Nectar is secreted in the flowers by a ring of the receptacle between the innermost stamens and the pistil, and the flowers are visited by a number of insects. The arrangements of the parts is such as to favour cross-pollination, though self-fertilisation is possible. The stigmas begin to be mature when the flower opens, and project in front of the stamens. The latter are bent inwards in the bud, owing to the curvation of the filaments, but straighten and diverge as they are ready to open.

Besides the Common Avens, the Water Avens (*Geum rivale*, L.) and a form which is intermediate between the two, and is probably a hybrid, are found in Britain.

The Bugle (*Ajuga reptans*, L.).

The Bugle is to be found in grassy land, usually in moister spots and in the shade of woods. It often grows in numbers in one spot. The flowering season is from May to July, and for the proper study of the plant a number of specimens with intact branches should be collected. It will be found that each plant (Fig. 98) consists of a short, underground stem, from which long whitish roots extend downwards. This bears a rosette of crowded foliage-leaves or their remains, and in the axils of some of the leaves buds can be seen, some of which have developed into prostrate branches or runners. The main stem continues into the erect flowering shoot. All these parts must be considered if we are to understand how the Bugle maintains itself and extends in the struggle with other plants.

The stem of the erect main shoot is square with somewhat rounded angles. Each node bears a pair of leaves, the pairs alternating at successive nodes. The leaves have simple blades, narrowing below where they pass into the leaf-base, but not very distinctly

stalked. The leaf-bases of the two opposite leaves may meet around the stem and form a short sheath. The leaves of the basal rosette have longer stalks. In the axils of the lower pairs of leaves only small buds may be present, but on passing upwards the leaves gradually diminish in size, and in the axil of each a cluster of flowers is present. As Fig. 98 shows, the two opposite groups of flowers appear to completely surround the stem. Each axillary group of flowers is a little inflorescence with greatly shortened flower-stalks. The central flower, immediately above the bract, is the first to open, and is then followed by flowers to either side borne laterally on the stalk of the central flower and so on. The whole arrangement resembles that in the Dead-nettle, a close relation of the Bugle.

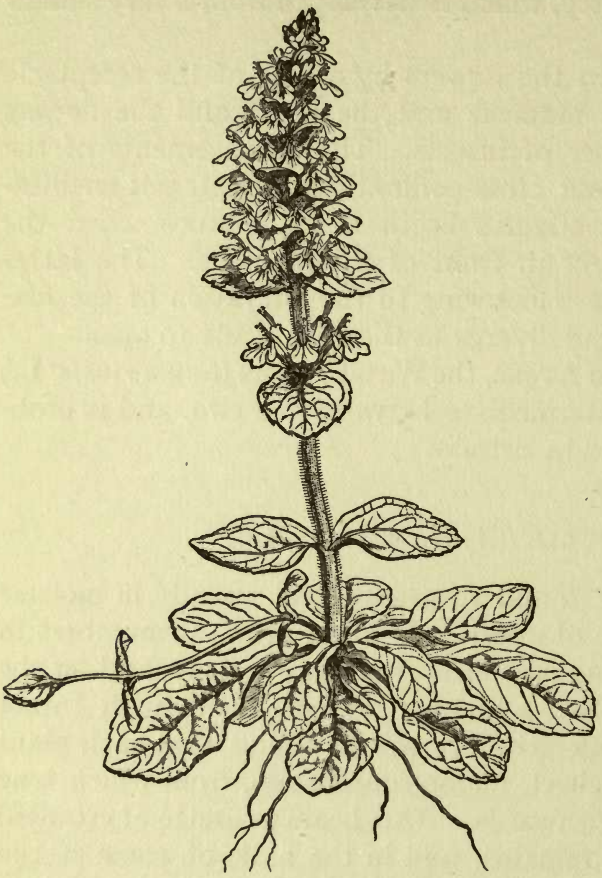


FIG. 98.—Plant of the Common Bugle in flower. (After Baillon.)

The flowers of the two plants are also constructed on the same plan, though with important differences of detail. In the Bugle (Fig. 99) the sepals are united to form a wide bell-shaped calyx, with five large teeth at the margin that indicate the number of the sepals. The margins and back of the lobes bear stiff hairs, while the lower tubular portion of the calyx is smooth and often bluish in tint. The petals are united to form a narrow

tube almost one-third of an inch in length. This is somewhat widened at the lower end within the calyx, and at the free end is divided into two lips of very unequal size. The upper or posterior lip is very short, and is formed of the projecting tips of two petals, which can be distinguished as small rounded lobes. The lower lip, on the other hand, extends in front of the tube as a three-lobed expansion of considerable size. The lobing indicates the three petals of which it is composed; the large petal forming the middle lobe is notched. The whole corolla is of a bright blue colour, some of the veins on the lower lip being a darker blue.

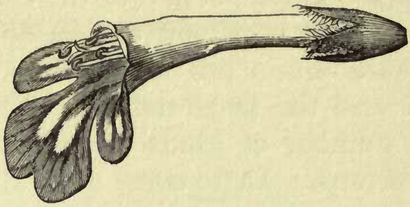


FIG. 99.—Flower of the Bugle seen from the side. (After Baillon.)

As in the Dead-nettle, there are only four stamens, the stamen which might be expected to alternate with the posterior petals being completely absent. In the Bugle, owing to the shortness of the upper lip, the stamens project beyond it, and are visible from the outside of the flower. They form two pairs, a longer and a shorter, so that two of the anthers stand in advance of the other two. All the anthers face downwards. On slitting up a corolla-tube the filaments will be found to be attached to the inside of this. The anthers, which project clear of the upper lip, at first stand close to the middle line.

FIG. 100.—Pistil of the Bugle showing the four-lobed ovary, the style and the two-lobed stigma. In front of the ovary is the nectary. (After Baillon.)

Behind the stamens is the forked stigma which ends the long style. If a corolla is carefully pulled away from the rest of the flower the style will be left in position, and will be seen to spring from the middle of four green shining bodies (Fig. 100). These are the four lobes of the ovary, and each encloses a single ovule. As the stigma, with its two lobes directed forwards and backwards, indicates, these lobes are derived from two carpels, as in

the Dead-nettle. On removing the calyx from around the ovary a yellowish gland will be seen at the base of the latter in front. This is the nectary, and the nectar secreted by it accumulates in the lower portion of the corolla tube.

If we now look at the flower as a pollination mechanism we shall obtain an explanation of some of the differences between it and the Dead-nettle. The flower of the Bugle is visited by a number of kinds of insects, of which bees are the most important. These come after the nectar stored in the base of the corolla, and, owing to the length of the tube, it is clear that only insects with fairly long tongues can reach the nectar and will visit the flowers. The insect alights on the expanded lower lip, and the back of its head and body will come in contact with the downwardly directed anthers and be dusted with pollen. Since, however, the stigma has its lobes, which are receptive on the inner surface, separated while the pollen is being shed, we might expect that the flower's own pollen would be deposited on the stigma. This may ultimately occur, but cross-pollination is favoured by the position of the stamens. The two shorter stamens, which are at first close together in the middle line, come between the insect and the stigma. In older flowers these stamens diverge somewhat from one another, and the style is no longer supported so that the stigma bends forward. The position that it now occupies is such that it comes in contact with the portion of the insect's back which is dusted with pollen from younger flowers.

The four lobes of the ovary enlarge after fertilisation, and the ovule within each develops into a seed. The lobes of the fruit do not open to set the seeds free, but the four lobes separate and are shed, each enclosing a single seed.

While the spread of the Bugle to any distance, and its establishment in a new locality, must depend upon the transport of seeds, the local spread of the plant is effected vegetatively. The prostrate branches, which were seen to be developed at the base of the plant, resemble in general features the erect shoots, but have a thinner stem with long internodes. Their leaves have longer stalks, and twist round so that the blades are exposed to the light. Roots spring from the nodes where they rest on the

ground. At any of these points or from the terminal bud a new plant may be established. It becomes free from the parent by the ultimate decay of the intervening region of the runner, and is at such a distance from the parent as to lessen the danger of competition. If we examine the base of a flowering plant we can often distinguish the end of the runner passing into the somewhat swollen stem described above.

The Yellow Iris or Flag (*Iris Pseudacorus*, L.).

Two kinds of Iris, of which much the commoner is the Yellow Flag (Coloured Plate), grow wild in Britain. The following description of this will, however, assist the student in examining other kinds of Iris, whether wild or cultivated, allowance being made for differences in detail. The Yellow Flag grows best in damp spots, in marshy ground and by the sides of small streams and ditches. It often occupies a considerable area, and its long erect bluish-green leaves and large yellow flowers make it a conspicuous plant during the summer. If the spot where it grew is examined in winter no trace of the foliage will be seen, only the underground parts remaining, as is the case with so many of our perennial plants.

Plants should be carefully dug up and the underground stem and roots washed free from the soil. Many of the stems will be found to end in vegetative shoots. Others, however, have projecting from among the foliage-leaves a tall inflorescence, which bears a succession of large flowers. The two kinds of shoot require separate study.

In a plant without an inflorescence we recognise the thick horizontal stem more or less completely covered by the soil. Its surface is brown, but when cut across the tissue within is pinkish. The older parts bear the remains of foliage-leaves of former years ; these are transverse scars almost encircling the stem. Projecting from them are long, brown, bristle-like threads, the remains of the more persistent tissues of the leaf-base. Two kinds of roots spring from the stem. From the lower surface a number of stout cylindrical whitish roots grow vertically down into the soil. They are at first unbranched, but later become attached to the soil by a

number of fine lateral roots. If the younger roots of this kind be compared with older ones the surface will be found to be at first smooth, and later to become wrinkled transversely. This shows that contraction has taken place, and these roots, in fact, serve to pull the horizontal stem firmly down into the soil, and are of subordinate use for obtaining food material. From the sides and upper surface of the stem, however, roots of a different nature spring. They are more slender, and bear numerous fine branches. Their appearance shows them to be purely absorptive in contrast to the fixing and contractile roots.

At the end of the leafless region of the stem we find the tip of the shoot turned somewhat upwards, and bearing the foliage-leaves. Through the bases of these leaves a number of young attaching roots project, and it is easy to realise how they correct the upward curve of the tip and pull it down into the ground. To either side of the terminal leafy shoot are smaller shoots, evidently developed from lateral buds of last year, and similar lateral buds may be seen farther back on the main shoot. Evidently this grows on for a number of years, producing lateral shoots most of which do not develop farther.

The leaves of the Iris are very remarkable. Each has a large sheathing base completely encircling the stem, and they succeed one another closely on opposite sides of the stem, so that they alternate in two ranks. The erect blade of the leaf is not, however, flattened in the horizontal but in the vertical plane. It appears as a pointed, sword-shaped outgrowth of the back of the leaf-sheath, showing not an upper and lower surface, but two similar flat sides. The veins run parallel in the leaf-blade.

We can carefully remove the leaves one after another from the shoot, and recognise how perfectly they enclose the summit of this. Small lateral buds will be met with in the axils of the leaves. Centrally the shoot terminates in a series of smaller and smaller immature leaves overlapping one another, and ready to develop into next year's foliage-leaves. The study of these with a lens will show the origin and enlargement of the leaf-blade.

When an inflorescence is not formed the shoot grows on year after year. If, however, a plant bearing an inflorescence such as that represented in the plate is examined the general features of

the underground stem (Rh.), the contractile roots (R^1), the absorptive roots (R^2), and the lateral buds borne on the sides of the stem (B) will be found as has been described above. The terminal leafy shoot, however, ends in a long green erect stem, the stalk of the inflorescence. Since the apex has grown into this, it cannot continue the growth of the shoot next season, and this must be carried on by one or more of the lateral branches.

The inflorescence consists of a cylindrical green stem with elongated internodes. It bears a few leaves of diminishing size, and with no branches in their axils. Then come smaller bracts, and the stem ends in the first flower. In the axil of one of these bracts stands the second flower, the stalk of which bears a single small bract; in the axil of this the third flower develops, and so on. Each axis ends in a flower, and produces another flower as its single lateral branch. The succession of flowers, which is not clearly shown in the plate, requires to be carefully looked for, since the opening flower always appears to stand at the summit of the shoot. Branch inflorescences may be developed in the axils of one or more of the lower leaves on the inflorescence.

The flower of the Iris is one of the most beautifully constructed arrangements to ensure cross-pollination by means of insects. Its structure and mode of working were made out by Sprengel, the discoverer of insect-pollination, and should be carefully studied in several specimens. Each flower has a rounded flower-stalk, which bears the bracteole mentioned above near its base. The flower-stalk, which lengthens just before the flower opens and thus carries it clear of the bracts, continues into the three-sided green, inferior ovary. If this is cut across it will be found to have three flattened sides, while the angles are truncated, and each shows a narrower groove. The three partitions extend inwards from the middle of the flat sides, and each of the three cavities has two rows of ovules springing from the central angle.

The perianth of the flower (Fig. 101) consists of six yellow leaves forming two whorls. The leaves of the outer series are broader and recurved, while the inner ones are narrow and erect. All six join together to form a short tubular region just above the inferior ovary. The inner surface of the tube is yellowish, and secretes the abundant nectar, which accumulates around the base of the

style. There are three stamens, attached to the inner surface of the larger perianth segments, and standing up opposite to these. Each stamen has a strong curved stalk and a large anther, the two lobes of which face and open outwards and downwards. Three styles spring from a cylindrical portion in the centre of the flower terminating the inferior ovary. The styles are broad and leafy, or petal-like, and they lie opposite to the broad outer perianth segments, and thus above the three stamens. Each stamen is thus enclosed between the perianth segment and the leafy lobe of the style, which fit closely together and hide the stamen. The tip of the style is two-lobed, and has a wide thin margin and is bent upwards. Just before this bend takes place a little projecting lip can be seen on the under or outer surface of the style. This is the stigma, the upper surface of the lip being the receptive surface. The fact that the branches of the style do not alternate with the stamens indicates that an inner whorl of three stamens is wanting in this flower. As a working arrangement in pollination each third of the Iris flower can be compared with an irregular flower. Humble-bees are mainly concerned in the pollination. These alight on the broad landing-place formed by one of the outer perianth segments, and, guided by the brown lines or honey-guides on this, will force it and the style apart. Having crept in between the perianth-leaf and the style, the bee can reach the nectar by a passage to either side of the stalk of the stamen, where this is attached to the perianth. In thus creeping into the flower the bee first rubs its back against

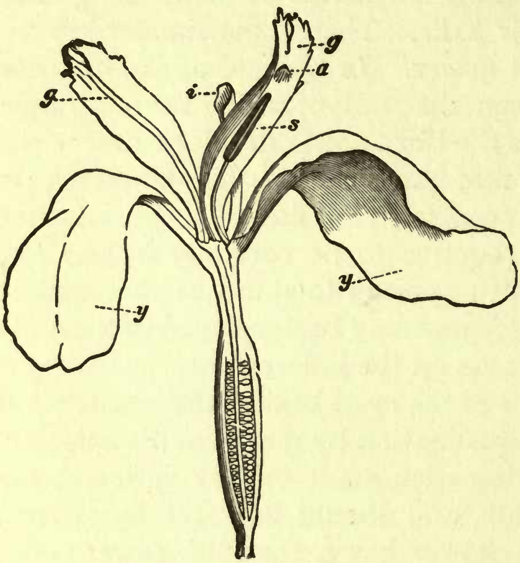


FIG. 101.—Flower of Yellow Flag cut in half. *y*, outer segment of the perianth; *i*, inner segment of perianth; *s*, stamen; *g*, branch of the style; *a*, the stigmatic lip. (After Warming.)

YELLOW FLAG (*Iris Pseud-acorus, L.*).

Rh. Underground stem. R¹. Attaching roots. R². Absorbent roots.
Infl. Base of inflorescence. B. Lateral bud.

the stigmatic lip and then against the downwardly directed open anther. On creeping out of the flower the pollen on the bee's back will only come in contact with the non-receptive side of the stigmatic lip. When a bee with pollen on its back enters another third of the same flower or another flower, the pollen will be deposited on the stigmatic surface of the scoop-like lip. If the visit is to another flower, cross-pollination will result. Consideration of the very beautiful arrangement of the parts in this flower shows that pollen cannot possibly fall on the stigma in the absence of insect visitors, and that insect visits may result either in pollination of the stigma of one third of the flower by pollen from the stamen of another third or in cross-pollination. The close fitting of the style on the perianth segment excludes small and weak-bodied insects which would be useless to the flower.

The fruit of the Iris consists of the enlarged inferior ovary, from the summit of which the withered remains of the rest of the flower has fallen. This becomes a dry capsule, which, like the ovary, is triangular on cross section. When ripe it splits along the three angles, thus opening the cavities from which the flattened seeds escape.

The Germander Speedwell (*Veronica Chamædrys*, L.).

A number of kinds of Speedwell are found commonly in Britain; some grow in ditches and damp places, while others prefer drier spots. The Germander Speedwell is readily recognised by its bright blue flowers and by the two lines of white hairs running down opposite sides of its stems. It can be found everywhere in dry grassy land and by roadsides, preferring open sunny situations.

The plant is perennial, and has a smooth cylindrical underground stem sending out numerous roots at the nodes. Branches arise from the axils of the reduced leaves borne on this stem, and grow up into the leafy shoots. Each of the latter has a cylindrical green stem, often tinged with purple, and bears a pair of leaves at each node. The successive pairs of leaves alternate, and they are separated by rather long internodes. The leaf, which has hardly any stalk, is inserted on the stem by a broad

sheath-like base. The blade is triangular in outline, and its edge is cut into large teeth pointing towards the tip. The surface is wrinkled, and the veins project strongly on the lower surface. Small stiff white hairs are scattered on both surfaces, and are more numerous on the veins below. Down each internode of the stem from the interspaces between the two leaves of the whorl run two lines of long white hairs. These rows of hairs thus alternate in successive internodes.

Inflorescences are developed in the axils of a number of the upper leaves. The lower portion of the stem of this is leafless, but on the upper part are numerous narrow simple green bracts, in the axil of each of which is a single flower. The stem is round and bears hairs on all sides, not in two definite rows. Another point of difference from the vegetative shoot is that the leaves are inserted singly and not in whorls of two. The flowers open in regular succession from below upwards.

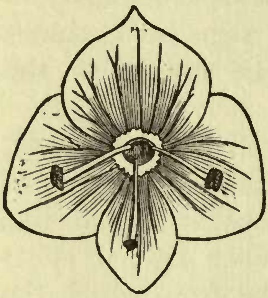


FIG. 102.—Flower of Germander Speedwell, seen from in front. (From Müller's *Befruchtung der Blumen.*)

Each flower has a slender flower-stalk, and consists of the following parts. The calyx is green and hairy, and consists apparently of four sepals. These are narrow and pointed, and only united for a short distance at the base. Comparison with the flowers of related plants, such as the Foxglove, shows that the sepal which should stand in the middle line behind is wanting. The petals forming the corolla are united, and the corolla is very readily removed or falls off in a piece carrying the stamens with it. It appears to be composed of four petals, which alternate in position with the sepals. Comparison with related plants shows, however, that the posterior petal is really the equivalent of two petals fixed together. This lobe of the corolla is broader than the others; the two lateral petals are also fairly broad, while the anterior petal is narrow (Fig. 102). The tubular portion of the corolla, from which the lobes in full-blown flowers expand almost at right angles, is very short. Looked at from in front, the blue petals are seen to be marked with deeper blue lines converging

towards the centre of the flower, and here the tubular portion of the corolla and the bases of the petals are white. The entrance to the tube is protected by a fringe of hairs around the lower margin.

There are only two stamens, which diverge widely in a fully open flower. They are inserted on the inner surface of the corolla tube, opposite the gaps between the broad middle segment behind and the lateral petals. The stalks are thin and curiously curved at their insertion on the corolla. Farther up the stalk has a blue colour, while the anther and the pollen contained within it are white.

The style, which projects from the corolla tube, is also slender and blue. It slopes downwards in front of the narrow anterior petal, and bears the small stigma farther forward than the other parts of the flower. The style springs from a flattened, green ovary, as is readily seen on removing the corolla from a flower. Careful dissection of the ovary, with the help of a good magnifying glass, will show that it is divided into two by a septum. Each half is, in fact, formed by one of the two carpels, which are united to form the pistil. In each cavity are a few ovules.

Around the base of the ovary is a narrow yellow rim which secretes the nectar, and it will be evident that this is accessible even to short-tongued insects. The nectar is not, however, openly exposed, as in some flowers, but is protected by the circle of hairs within the corolla-tube. The flowers are visited by a number of insects, but especially by small flies, to which they are specially adapted. These come in search of the nectar. If, as is usually the case, the fly approaches the flower on the wing immediately in front, the first part of the flower to come in contact with the lower surface of its body will be the stigma. Alighting on the flower, the insect may be seen, in trying to gain a foothold, to grasp the bases of the stamens and to draw them together with its legs, thus rubbing the anthers against the under surface of its body. This region will, after visiting a flower, be dusted with pollen, and on the insect going to another flower the stigma will receive some of this. If the position of the various parts in the open flower is taken into account it will be readily understood that the pollen would not be likely without insect agency to get from the anthers,

borne to either side on long stalks, to the stigma, projecting in the middle line in front. The whole apparatus is, however, suited for cross-pollination by the help of small flies, and the way in which it works can be verified by careful observation of a group of the plants on a sunny day. The reduction in number of the stamens to two is an indication of the precision of the method of pollination.

That fertilisation is effectively carried out is evidenced by the number of ripe fruits borne by the inflorescences later in the season. These are developed from the enlarged ovary, and are still surrounded by the calyx. The capsule has the shape of a flattened, inverted heart, and in each cavity are several seeds. These are shed when the ripe fruit opens.

END OF VOL. III.

Printed by MORRISON & GIBB LIMITED, *Edinburgh*